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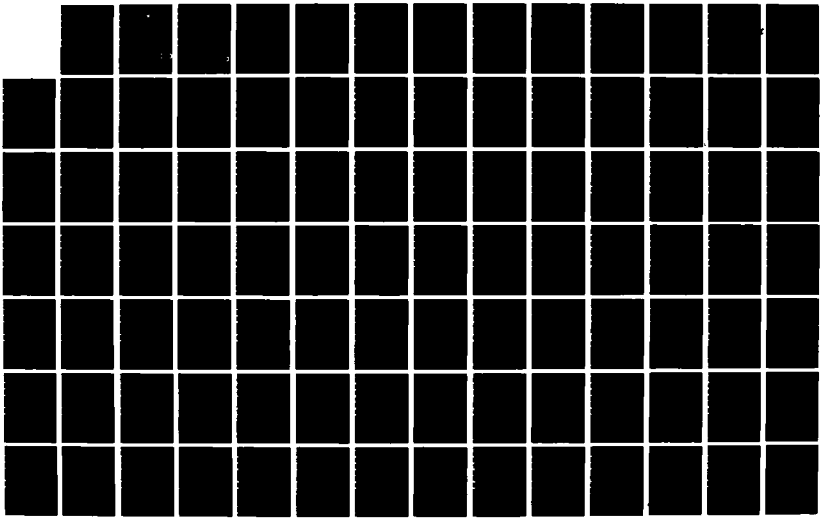

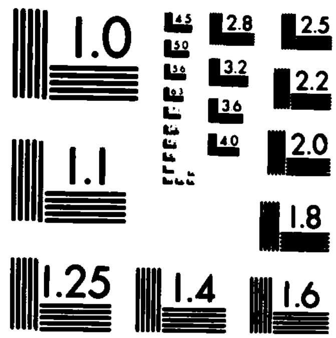

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UNITED STATES AIR FORCE

AIRCRAFT MODIFICATION PROCESS:

A SYSTEM DYNAMICS ANALYSIS

THESIS

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UNITED STATES AIR FORCE
AIRCRAFT MODIFICATION PROCESS:
A SYSTEM DYNAMICS ANALYSIS

THESIS

Presented to the Faculty

of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

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Preface

The purpose of this study was to develop a conceptual model of the Air Force aircraft modification process which truly represented the way the process works. This topic was chosen for two reasons. First, the modification process has the reputation of being difficult to understand, which made any study of it a challenge. Secondly, modifications are becoming increasingly important as a means for increasing and maintaining the capability of aircraft, and so are receiving more attention than ever before. This made study of the process timely, and the results potentially of use to those who wish to learn about the process, and those who oversee it.

We recognize that readers may have different reasons for reading this study, and so we wish to provide a guide to it. Those who are interested in a summary and the recommendations of the study should read the introduction and statement of the problem in Chapter I, and then turn to Chapter IV. If more depth is desired, Chapter III should be read, and the Glossary of Variables in Appendix B can be used as a reference for that part of the discussion that specifically depends on Chapter II. Those who desire understanding of the modification process should read Chapters II through IV, with reference to Appendix A, B, and C.

Acknowledgements

We wish to acknowledge the many people who provided assistance to us in the research project. Foremost is our thesis advisor, Lt Col Thomas D. Clark, whose experience and expert guidance kept the research on track. We thank him not only for his guidance in this research, but also for his leadership and exemplary officership. Lt Col David Zorich, on the Air Staff, and Lt Col Larry Meylink, on the staff at Air Force Logistics Command, devoted many hours to building our understanding of the modification process, and to ensuring that the model truly represented that process. We also thank Mr. James E. Williams, Deputy Assistant Secretary of the Air Force for Acquisition Management, who sponsored the research, for his invaluable support and interest. Mr. Grover L. Dunn, Deputy Chief of Aircraft Systems, and Ms. Joyce B. Lucky, of the Modifications Programs Branch, provided significant insights into the process. We also thank the many others who generously gave us their time and the benefit of their experience and knowledge.

We particularly thank Hal's wife, Rebecca, and Ro's husband, Bill Selah, for their understanding and cooperation through the long process of this study. Finally, this project could never have been completed without our computers and the MultiMate word processor. So, IBM, DEC, and MultiMate International Corporation receive our thanks.

Rosanne Bailey　　　　Harold F. Stalcup

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Abstract

A conceptual model of the Air Force aircraft modification process has been developed and validated. The model was designed using the system dynamics technology. Sources of information included both literature research and personal interviews. The personal interviews were conducted with Air Force, DOD, OMB, and Congressional people active in the aircraft modification process. Five key issues concerning the behavior of the system were identified and detailed. These issues were: the lack of a systems approach to modification management, the absence of a Class IV requirements approval process, the difficulties of management split between AFSC and AFLC, the priority ranking of modifications by the financial community, and the weaknesses of the process which are currently overcome by strong individuals. Five recommendations for change to the modification process were presented. The recommendations were to establish a requirements review, approval, and ranking process for Class IV modifications, encourage a systems approach to management, improve the credibility and understanding of the process, and encourage competition by several means. Use of the conceptual model provides the manager with a deeper understanding of the complex modification process and can provide greater visibility into the potential outcomes of policy changes.

UNITED STATES AIR FORCE
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I. Problem Definition

Introduction

The Honorable Richard D. DeLauer, Undersecretary of Defense for Research and Engineering, said to the 98th Congress that the goal of modernization for the Department of Defense "is to have capable, affordable forces equipped to adapt to new and evolving threat environments, new theaters of operation, and political and economic discontinuities." In his presentation of the fiscal year (FY) 1984 DOD Program for Research, Development, and Acquisition to the Congress, Dr. DeLauer emphasized the combination of affordability and modernization. In his words,

> an affordable "modernized" force requires that it be equipped with a combination of (1) advanced technology where that is appropriate, (2) product improvements where these will make a needed difference, (3) new items of older equipment still adaptable to the tasks ahead, and (4) older equipment which is still serviceable and suited to modern environments [13:4].

In recent years the modification of existing systems to achieve desired capability has been increasingly advocated as the quickest and most cost-effective way to achieve a modern force under severe budget constraints. The B-52 Stratofortress, which has been in service for three decades, is a prime example of how modification of an existing system can support evolving requirements. Since its initial deployment in the early fifties, the B-52 has appeared in eight models and has undergone continuous modification. Although it is old and its basic technology is obsolete, the B-52 carries modern avionics, munitions, engines, even infrastructure and skin, all installed to support the requirements of meeting a modern threat and to keep an old airplane safe and effective.

Thus the DOD sustains the weapon systems for an effective United States defense posture in two ways. The first is through the design, development, acquisition, and deployment of new weapon systems. The second way is the modification of existing systems to add new capabilities, to correct deficiencies, and/or to extend their operational life. As previously stated, modification is becoming increasingly important as the cost of new systems skyrockets, and the federal budget receives closer scrutiny and harsher criticism.

In FY 83, the Air Force spent $2.558 billion on the procurement of modifications for aircraft. This does not include the research, development, or installation of those

modifications, nor any modifications to other than aircraft systems. The FY 83 budget showed a 19 percent increase over FY 82 for aircraft modifications, while the overall defense budget increased less than 10 percent in the same period (16:24). This increase in the portion of the defense budget devoted to modifications appears to be an increasing trend, as illustrated in Table I (47:230).

TABLE I

Aircraft Modification Funding (47:230)
(procurement $ millions)

FY 83	FY 84	FY 85
2,475	2,657	3,423

Although the aircraft modification process consumes a significant and increasing fraction of the Air Force aircraft acquisition budget—17.8 percent in FY 84 (Fig. 1.1)—until recently the process itself has not received as

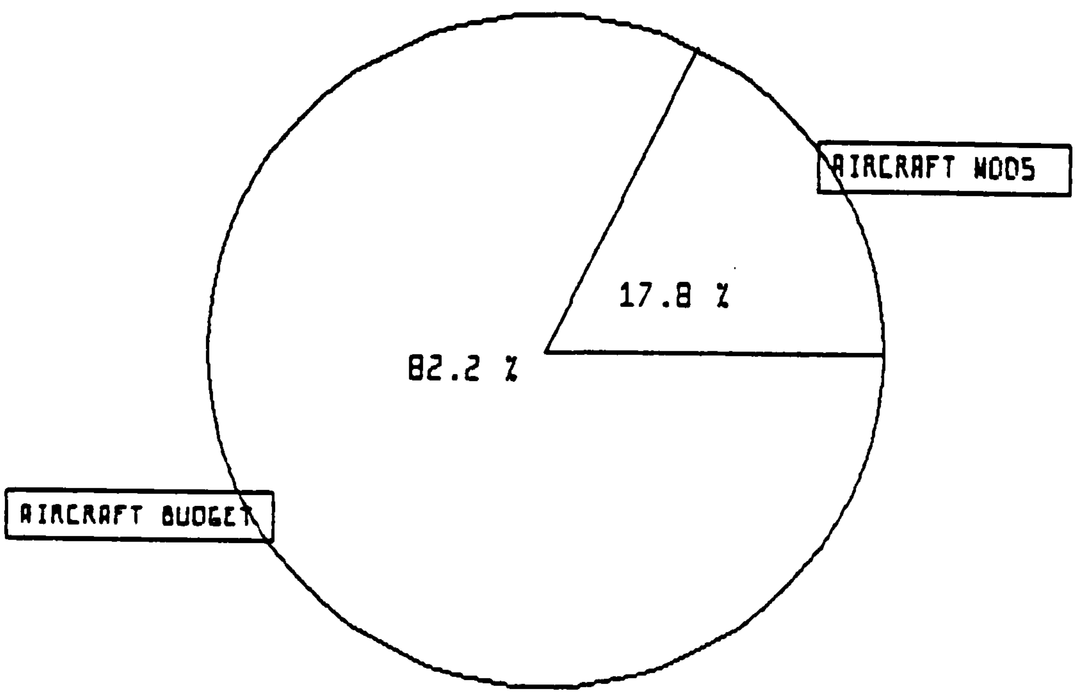


Fig. 1.1. Aircraft Modifications as a Percentage of Total Aircraft Acquisition Budget [47:230].

much detailed scrutiny as has the basic system acquisition process. Both methods (modifications and new acquisition) are derived from the philosophy of OMB Circular A-109, Major System Acquisition, on which all current acquisition regulations, directives, and policies are based (39). However, the Acquisition Improvement Program (AIP), begun in 1981 with the Reagan Administration, is primarily aimed at the new-system acquisition process. Although the AIP initiatives benefit the modification process, the study which led to AIP did not specifically investigate the modification process as it did the basic acquisition process.

Recently, more interest has been directed at the modification process. As the study reported here was in progress, Lt Gen Chain (then HQ USAF Deputy Chief of Staff for Plans and Operations) briefed the problems of the Class V modification process to the Air Force four star commanders (7). Directed from that meeting was what is now known as the Chain Study, which specifically investigated the length of time it takes, from inception to completion, to do a Class V modification. The results of that study, and its recommendations, were briefed to the Air Force Council on 22 May 1984 (52). However, this study focused on symptoms, not any underlying structural problems that might exist (51). Consequently, there is only one known current study of the modification process, and it does not examine the process as it actually works (as opposed to how the regulations, directives, and policies say it should work).

The documents that purport to regulate the modification process present a problem of their own. Most of the regulations specific to major modifications are dated from the mid to late 1970s, or have been in revision for several years. None are current relative to the latest version of the Department of Defense Directive (DODD) 5000.1, Major System Acquisition issued 29 March 1982 (20), and DODD 5000.2, Major System Acquisition Process, issued 12 April 1982 (19).

Nowhere is the entire process described, defined, and presented for the information and study of the manager. Many of the regulations are out of date and fragmentary. Studies, if current, treat pieces of the system, or symptoms of the problems inherent in that system. To further complicate matters, the modification process is extraordinarily complex. It is difficult for the manager to develop an intuitive grasp of a system as complex as the modification process (50:3). Therefore, the policy-maker or decision-maker can be in the position of making decisions whose impacts are unknown or only dimly guessed. For the money involved, and the criticality of the weapon systems involved, this situation is untenable.

Problem Statement

The problem, therefore, is to capture the significant aspects of the aircraft modification process and present them in a form that can be used to amplify the experience

and judgement of the decision-maker where critical decisions are being made. The significant aspects of the process are expected to include modification resource (funds) allocation.

<u>Objectives</u>

"To capture the significant aspects of the process of aircraft modification" implies an understanding of how the modification process is actually conducted. Delving into regulations provides the "supposed to" part; investigating actual cases and interviewing the managers and policy-makers within the process provides the "what really happens" part. The objective is to capture what really happens in the process.

"In a form that can be used to amplify the experience and judgement of the decision-maker" suggests a condensation of the experiences and information gathered above into a documented tool available to managers. In this case, a conceptual model is built to simulate the actual workings of the aircraft modification process and to allow the manager to consider the effects of policy changes on the operations of the process. The final goal of this research effort is a model that is understandable by the end user (policy-makers and their staffs), that truly represents the structure of the system, and that enhances the decision-maker's assessment of potential policy changes.

Background

In this section the background of the study is presented. It reviews the basis of aircraft modification, the background of system dynamics which is the research method employed, and the application of system dynamics to the aircraft modification process. To facilitate this review, operational definitions of some critical terms are provided first. In Appendix A a complete Glossary of Terms and Acronyms is provided for easy reference.

Definition of Terms. Provided below are the operational definitions of critical terms used in this study.

Aircraft Modification as defined by DODD 5000.8 and excerpted by the Compendium of Authenticated Systems and Logistics Terms, Definitions, and Acronyms is "a change in an airframe, component, or equipment that affects performance, ability to perform intended mission, flight safety, production, or maintenance" (15:459).

Classes of modification - AFR 57-4 (14:3-4) provides a descriptive breakout of modifications into five classes by rules and approving authority.

Class I - A temporary removal or installation of, or change to, equipment for a special mission or purpose.

Class II - A temporary modification to support research, development, or operational test and evaluation efforts.

Class III - Modifications required to insure production continuity.

Class IV - Modifications to insure safety of flight, to correct a deficiency which impedes mission accomplishment, or to improve logistic support.

Class V - Installation or removal of equipment changing the mission capability of the present system configuration.

Dynamic problems - Problems that involve quantities which change over time and that incorporate the concept of feedback.

Feedback - The transmission and return of information. A feedback loop is a closed sequence of causes and effects, a closed path of action and information [42:3,4].

Policy - An accepted or settled way for approaching a problem, determined by appropriate authority and passed through guidance to subordinates. Each organizational echelon may thus establish policy when interpreting or providing guidance on policy received from higher authority [15:527].

Simulation is a technique used to describe the behavior of a real-world system over time. Most often this technique employs a computer program to perform the simulation computations [3:540].

System dynamics is a profession [or approach] that integrates knowledge (mostly descriptive) about the real world, with the concepts of how feedback structures cause change through time, and with the art of computer simulation for dealing with systems that are too complex for mathematical analysis [26:7].

Basis of Aircraft Modification. War fighting capability is created or increased through the weapon system research, development, and acquisition process; this is generally known. Less well known is the role that modification plays in adding to and maintaining weapon system capability.

New weapon systems first enter the operational inventory with deficiencies--parts, components and subsystems that do not work as well as expected. Some of these deficiencies are minor defects, some are demonstrating infant mortality (failures of systems due to manufacturing defects or bad parts or components), others are design errors or poor production work. If the problems are caught early and

fixes insisted upon, correction of these deficiencies may be made through the developer, usually Air Force Systems Command (AFSC), and its contractor. Many problems--perhaps most--are inherited by Air Force Logistics Command (AFLC) and are later corrected through the aircraft modification process. Correction of deficiencies is accomplished through Class IV modifications, or Class III modifications if the aircraft is still in production under AFSC control.

Missions for aircraft change, which can result in a requirement for additional or reduced capability for existing aircraft. Changes (usually increases) in capability are incorporated into existing aircraft through the modification process. The incorporation of additional capability and the removal of unneeded capability is accomplished with Class V modifications.

The aircraft modification process is a complex and dynamic system which converts proven technology into operational capability. Over the past four fiscal years (FY 80 - FY 83), the USAF has spent over eight billion dollars on Class IV and V modifications (25:24). By the admission of managers within the modification process, it is a slow, cumbersome, and complex process. Managers lack a working understanding of the formal and informal policy and decision structures of the process. Without an accurate mental model of the the process, managers make decisions that tend to suboptimize their program's progress (1:3-15).

Conventional search techniques yielded very few current sources for information on the modification process. Several previous Air Force Institute of Technology (AFIT) theses were found to contain vast quantities of information, but at a level of detail far lower than the structural or policy level. Other studies focused on specific problems like the length of time it takes to implement a modification (7; 52)--but then never presented the results in report form. Only briefing charts and oral accounts were available. The literature used in this study included DOD reports, regulations or system dynamics studies (2; 7; 11; 13; 14; 16; 25; 31; 47; 50; 52). Specific examples came from interviews, from the Encyclopedia of US Air Force Aircraft and Missile Systems (32), or from Baumgartner's Systems Management (4).

The foremost regulation was Air Force Regulation (AFR) 57-4, Modification Program Approval and Management, dated 23 May 1983 (14). This is one of the few regulations current enough to reflect the policy of the present administration. AFR 57-4 establishes modification policies, defines the classes of modifications, and defines the structure within which modifications should be processed. Flow charts and key steps of the process are provided in the regulation and copied here in Appendix C. AFR 57-4 provided major contributions to the study. DOD Directive 5000.1 (20), and Instruction 5000.2 (19) provided the major

system acquisition process and policies which are the foundation for the modification process.

Useful background information and development of the idea that modification is an alternative to new system development were contributed by the 1979 Air Force Institute of Technology (AFIT) thesis by Klein and Smigel (31). A Rand report on the effectiveness of acquisition policy provided insight into external influences that affect funding for programs and the importance of stability in program personnel (21:4,15-17). These studies and regulations will be discussed as the conceptual model is developed in a later chapter.

Background of System Dynamics. System dynamics forms the basic foundation upon which the research methodology of this study is built. In this section, a discussion of system dynamics is presented with a following section describing the application of system dynamics to the aircraft modification process. System dynamics is a technology which allows a researcher to describe a dynamic system (such as the USAF aircraft modification process) analytically and to simulate that system over time. System dynamics also provides a technical language with which to communicate concepts concerning a complex system. The ability to communicate on a common level of understanding allows for the exchange of ideas and information between researchers and managers, and among managers. The topics

covered here include a discussion of policy analysis through the use of simulation models, an overview of policy analysis, and a description of the modeling environment.

For the purpose of this study, policy is "an accepted or settled way for approaching a problem, determined by appropriate authority and passed through guidance to subordinates" (15:527). Policy analysis becomes the study of a system in terms of its policies and the effects of changes in policy.

A description of how management and decision-making interact with policy is given by Jay W. Forrester:

> Management is the process of converting information into action. The conversion process we call decision-making. Decision-making is, in turn, controlled by various explicit and implicit policies of behavior. As used here, a 'policy' is a rule that states how the day-to-day operating decisions are made. 'Decisions' are the result of applying the policy rules to the particular conditions that prevail at the moment [27:93].

Most dynamic systems exhibit a synergistic effect from the interactions of the components of the system. In other words, the whole is greater than the sum of its parts. Components of the system can have compounding effects on one another and yield unexpected results. This synergistic effect can actually form the essence of a system - what makes it work. As Forrester says, "...the interconnections and interactions between the components of the system will often be more important than the separate components themselves [27:6]." In policy analysis, these interactions and

interconnections are identified, designed into a model, and tracked. The long term dynamic effects of policy changes on the system can be described using this information.

Forrester is the originator of industrial dynamics, which since 1961 has evolved into system dynamics. His description of industrial dynamics is relevant for present day system dynamics. Forrester's approach is still used today to capture the essence of a dynamic system. He writes:

> Industrial Dynamics [system dynamics] is the study of the information-feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise [26:13].

Forrester's approach was further developed by Richardson and Pugh in their book Introduction to System Dynamics Modeling with DYNAMO (42). The same activities occur, but Richardson and Pugh have condensed Forrester's ten steps of the approach into seven steps. For this study the seven steps were followed. In Table II the two sets of steps are displayed. Following the table an overview of the system dynamics approach to modeling is shown in Figure 1.2.

TABLE II

The System Dynamics Approach [26:13; 42:16]

FORRESTER	RICHARDSON-PUGH
1. Identify a problem	1. Problem identification and definitions.
2. Isolate the factors that appear to interact to create observed symptoms.	
3. Trace cause and effect information-feedback loops that link decisions to action to resulting information changes and to new decisions	2. System conceptualization.
4. Formulate decision policies that describe how decisions result from available information streams.	3. Model formulation
5. Construct a mathematical model of the decision policies, information sources, and interactions of the system components.	
6. Generate the behavior through time of the system as described by the model.	4. Analysis of model behavior.
7. Compare results to historical data from the actual system.	
8. Revise the model until it is acceptable as a representation of the actual system.	5. Model evaluation
9. Use the model to test modifications to the system.	6. Policy analysis
10. Alter the real system in the directions that the model experimentation has shown will lead to improved performance.	7. Model use or implementation.

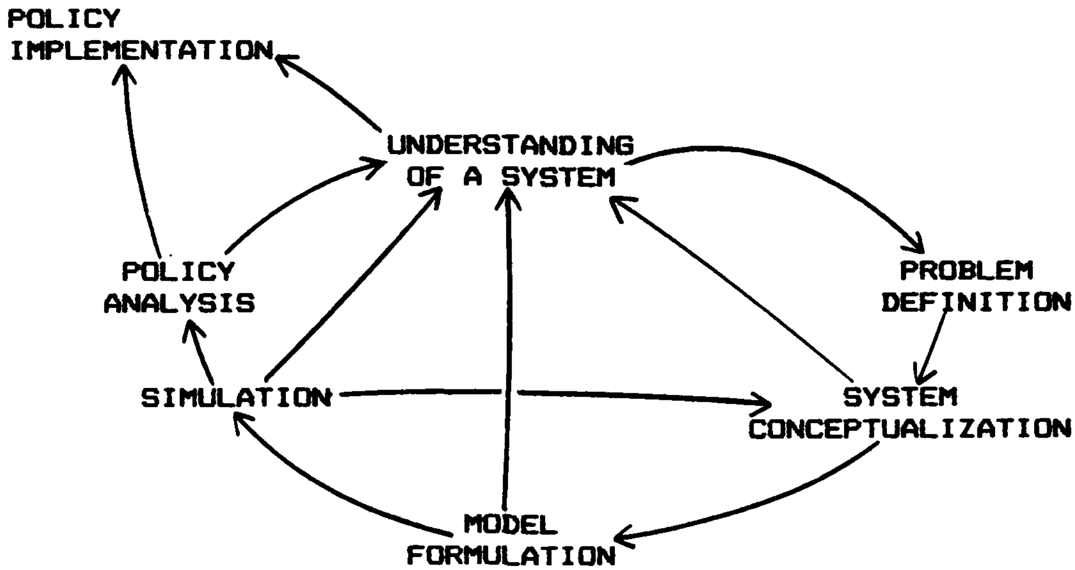


Figure 1.2. Overview of the System Dynamics Modeling Approach [42:Fig.1.1]

The aircraft modification process fits the characteristics of a dynamic system with information-feedback. System dynamics is well suited to the attempt to capture the essence of such a large, complex system. These factors drove the selection of systems dynamics as the basic methodology for this study. The next section describes the methodology of this study.

Methodology

The USAF aircraft modification process displays the characteristics of a dynamic system with information-feedback. The system dynamics approach to policy analysis

simulates dynamic systems. Therefore, the system dynamics approach or methodology will be used in this study to model the aircraft modification process.

"Models are representations of real objects or situations...[and they] represent the real situation by a system of symbols and mathematical relationships or expressions" (3:7). The greatest value of an accurate model is found by using it to study, analyze, and experiment on a system without changing the real system. Real systems should not be used for experimentation for several reasons. It would be time-consuming to make changes and wait for effects to observe and measure. Mistakes, or unsuccessful experiments would be too expensive in terms of people, dollars and potentially goodwill. Finally, in the real system, too many variables can not be controlled. This leaves the experimenter unsure whether the policy change or chance caused the observed results. This is the way, however, that most policy changes are currently tested in the DOD. New administrations change policies and before the results are really starting to show, change policies again. Or, the administration changes again and the entire approach is revised (5; 23).

Basically the seven steps on the right side of Table II were followed in the research. Unlike the final result suggested there, this effort does not result in an operating computer model. The original plan was to provide a

parametric model for computer testing. It quickly became clear, however, that the aircraft modification process is even more complex than had been originally thought. Since time is a severe constraint, effort was concentrated on producing a throughly documented conceptual model that would contribute to system understanding by policy-makers in various parts and at various levels in the system.

The scope of this study, as has been readily apparent throughout this introduction, is limited to Air Force aircraft modifications because most modification dollars are spent on aircraft. Furthermore, the modifications process examined is limited to the process that incorporates Class IV and Class V modifications, because these constitute the majority (in terms of dollars) of modifications. Finally, OMB Circular A-109 substantially changed the entire process of systems acquisition and modification; therefore this study was limited to examining the modification process after the A-109 publishing date of 5 April 1976 (39).

With an outline of the research methodology complete, attention is turned to the relationship between the aircraft modification process and system dynamics. The following section deals with past system dynamics studies concerning the aircraft modification process and how these studies relate to the current research effort.

<u>System Dynamics in the Modification Process</u>. As discussed earlier, very few studies have investigated the

modification process. Of the few that exist, only two could be found that use system dynamics as the technique to model the structure of the process. The earliest, by Lt Col Thomas D. Clark, "established a methodological foundation for further development of a functioning policy model, [11:1]" to quote his introduction. In this study the focus was on the Air Force Logistics System as a whole, not the more narrow aircraft modification process. Nonetheless, the process orientation of the study, together with the identification of critical decisions and information elements provided substantial background for the current study.

The second study which employed system dynamics to model the modification process was an Air Force Institute of Technology (AFIT) thesis by Mr. Michael Y. Fong and Capt Charles F. Hiser, titled A Systems Dynamics Policy Analysis Model of the Air Force Aircraft Modification System (25). This 1982 study focused in on the aircraft modification process and actually resulted in a computer model. However, the model, which was based on Lt Col Clark's model of the logistics system cited above, used as sources only the regulations governing the process and interviews with staff-level personnel at HQ AFLC. While these are valuable sources, and necessary for a full understanding of the process, the perspective of policy-makers was omitted. Consequently, the Hiser and Fong thesis limited itself to

modeling the aircraft modification process as specified in regulations and directives. In any case, Hiser and Fong contributed to understanding of the role of threat in the mod process and a beginning point for the review of the literature for this study.

While there were only two system dynamics studies of the aircraft modification process, a detailed model of the DOD acquisition process was available. This model was developed by Capts Whittenberg and Woodruff for their 1982 AFIT thesis titled Department of Defense Weapon System Acquisition Policy: A System Dynamics Model and Analysis (50). Their thesis, which was based on previous studies and interviews with policy-makers in Washington, D.C., contributed to this study the basic structure of the budget enactment process, the requirements development process including the role of the enemy threat, and the requirements approval process. Both requirements segments mentioned helped the Class V modification requirements structure development because Class V modifications and major system acquisitions are nearly identical in that respect.

The system dynamics studies identified above, combined with the other references reported earlier formed the background for this study. The specific methodology for the study follows.

Problem Identification and Definition. In this first step of the system dynamics approach the problem is identified and defined. Then the factors which appear to interact to produce system behavior must be isolated.

The problem was identified and essentially defined earlier. The aircraft modification process is defined by its regulations or guidelines and by the people who manage it. In this step of the model development, review of the existing literature and initial interviews with the primary managers of the process yielded an initial understanding of the structure and interacting factors of the modification process. Regulations and manuals governing the process were studied to identify the structure that underlies the process, and the policies that are officially in force. Previous studies of the aircraft modification process were reviewed for insights. Reports on the system acquisition process, on its effectiveness, and on its problems were reviewed to locate factors and influences common to the two processes.

Unstructured interviews with experienced managers, decision-makers and policy-makers were conducted to illuminate those areas of the actual modification process which differ from the process described in the regulations. The guide used in these interviews is provided as Appendix D. Managers at the headquarters of the supporting command, Air Force Logistics Command (HQ AFLC), at the headquarters of

the developer command, Air Force Systems Command (HQ AFSC) gave their perceptions of the real workings of, and problems with, the process. Staff analysts at Air Force Headquarters (HQ USAF) provided another view. Top policy-makers in the offices of the Secretary of the Air Force and the Secretary of Defense provided further insights. Staffers from the House and Senate Armed Services Committees provided their view of the process, from the budget enactment side. Analysts at the Office of Management and Budget explained their role in the process.

After reviewing the literature, and conducting the interviews detailed above, sufficient material had been collected to pursue the next stage of this step. Important factors in the system were listed, and influences on the factors were identified and added. Boundaries for the entire process were tentatively defined.

System Conceptualization. The second step in the system dynamics approach involves the conceptualization of the modification process as a dynamic system of factors and influences connected to one another through cause and effect relationships. For a large system this requires division of the system into sectors which can be examined individually for study, but which interact just as the factors within the sectors interact. For each sector, a causal loop diagram is created. A causal loop diagram is simply a picture of the causal relationships in the air-

craft modification process. The elements or factors are listed by name and linked by arrows which indicate the direction of the cause-effect relationship. Then the type of relationship--whether direct or inverse--is indicated by the plus or minus sign at the head of the arrow. A more detailed explanation of causal loop diagrams is provided at the beginning of Chapter II.

For this study the causal loop diagrams form the conceptual model of the aircraft modification process. It appeared in earlier system dynamics studies of the acquisition and modification processes that too little emphasis was placed on the conceptualization step. Consequently,the eventual computer model in those studies ran, and stabilized, but had unrecognized errors in the basic structure of the system. In this study, therefore, the greater emphasis placed on the conceptual phase required that the computer model be deferred to future research. The organization, development and documentation of the causal loop diagrams became very important. The model formulation step, therefore, was included in the second step.

To begin the conceptualization step, potential sectors of the aircraft modification process were identified in order to break it into manageable segments. Using the information gathered during the first step, the causal loop diagrams were developed. Each diagram grew by relating one factor to another, and then adding another with its rela-

tionships, and continuing in the same manner while related factors remained. When the diagrams appeared to reasonably represent the process as understood at that point, the second set of interviews were scheduled. The work of the second and third steps was complete, at least in the first iteration.

Analysis and Evaluation of Model. In the fourth and fifth steps of the system dynamics approach, a computerized model would be run to generate the behavior of the system. The graphical result would then be compared to historical data from the real process, and the model would then be revised until it fairly represented that real process. With a model in the form of causal loop diagrams, the same sort of analysis and evaluation is carried out, but in a different way. Obviously the conceptual model cannot be operated. Verbal explanations and discussion of the diagrams with experts is, however, a reasonable approximation. The technology of the causal loop diagrams is easy to pick up; given that, those knowledgeable about the modification process can quickly see in the diagrams the misrepresentations of the real process. In the interview environment, revisions to the causal loop diagrams can be made easily on pencil copies, and thus permit continuous refinement of the model. Comparison of the model's workings to historical behavior takes place in the discussion during the interviews, normally in the form of examples to illustrate a point.

The second set of interviews conducted during this study were used in the way described above. The HQ AFSC and HQ AFLC interviewees were revisited. In HQ USAF early sessions concentrated on getting the basic system right. In later sessions, which included individual interviews with three Deputy Assistant Secretaries of the Air Force, including the Principal Deputy, the focus was on strategic insights and a "view from the top." Significant revisions were common with whole new subsectors created and revised in response to interviewees' suggestions. The increasing validity of the model was measured by the reduction in the number of suggested changes as selected interviewees were revisited, in some cases four or five times. Writing the system structure (Chapter II) to accompany the diagrams documented the model and resulted in further refinement of the model. Chapter II is the output of the first four steps and it includes the causal loop diagrams.

<u>Policy Analysis</u>. In this sixth step of the system dynamics approach the model is used to test changes to the system modeled. In a computer model, changes to equations, or constants, or the shape of functions would simulate insertion of a new policy into the process. In the model used in this study, the effects of current policy can be traced through the causal loop diagrams. While minute changes cannot be discerned, and precise measurements are not available, major structural difficulties can be

identified. In this study, the causal loop diagrams of the aircraft modification process were used to identify the strategic implications of the current structure, the policies (where they exist) that affect the workings of the structure, and the deficiencies in the process that became apparent during the modeling process. The output of this step is Chapter III, Model Validation and Problem Analysis.

Summary. Within this section, the methodology to be followed for this study has been outlined. The system dynamics approach was applied to the study of the USAF aircraft modification process to develop a conceptual model of the process. The information needed to develop the model came from the literature and from interviews with experts and decision-makers. Validation of the model followed the Turing method (described in Chapter III) of employing experts to review the model structure.

Overview of the Study

In this first chapter the aircraft modification process was introduced, the problem for research was identified and defined, and objectives of the study were established. The background of aircraft modification, of system dynamics, and of system dynamics applied to the modification process were all reviewed. Finally the methodology followed in the study was presented. In Chapter II the structure of the aircraft modification process is presented in the form of causal loop diagrams accompanied by extensive narrative.

Thus the conceptual model is set forth. In Chapter III the process of model validation is described followed by a summary of key issues and problems identified in the modeling process, and Chapter IV presents a summary of the study, the conclusions resulting from it, and the recommendations of the authors.

II. The System Structure

Introduction

In this chapter the results of study and interviews are presented. The form used is a structural picture of the process of aircraft modification known as causal loop diagrams. While a brief explanation of causal loop diagrams was presented in Chapter I, a more detailed discussion is appropriate now to permit full understanding of the diagrams which follow. As described earlier, a causal loop diagram is simply a picture of a process or system whose characteristics or elements have been identified and related to one another. The elements are treated as variables and provided names that describe them as closely as possible. Each element is behaviorally oriented in that, it describes some behavior in the system. For example, the variable "MAJCOM support factor" describes the behavior of a using major command towards some proposed modification. A more detailed explanation of each variable is provided in the Glossary of Variables, Appendix B.

The elements of the causal loop diagram are linked to one another in pairs, in a cause-and-effect relationship. This relationship is signified by an arrow, at whose tail is the causative variable. At the head of the arrow is the variable on which the effect of the causative variable is demonstrated. This relationship is then qualified as

direct or inverse. A plus (+) sign at the head of the arrow indicates that the relationship is direct; that is, an increase in the variable at the tail of the arrow causes an increase in the variable at thehead of the arrow. A negative (-) sign indicates the relationship is inverse; that is, an increase in the variable at the tail of the arrow causes a decrease in the variable at the head of the arrow. During the discussion of the causal loop diagrams, the sign of the relationship is always tested using an increase in the causative variable.

The resulting pairs form loops which include feedback relationships and taken together, describe the entire process or system. A complete loop of these arrow-linked variables may be positive or negative. If the product of all the plus and minus signs in a complete loop is positive, then the loop is positive. If the product is negative, then so is the loop.

The causal loop diagrams form the foundation of the conceptual model presented herein. In the section that follows, an overall picture of the model will be presented. It will be used as a guide during the discussion of the causal loop diagrams of the modification process. Following that section, the individual sectors of the model will be explored in depth. Full understanding of the discussion will be facilitated by following it on the diagrams.

Overall Sector/Subsector Flows

In order to examine manageable pieces of the modification process, it is divided into four major sectors, each of which has one or more subsectors. The four major sectors are the requirements/capability sector, the financial sector, the development sector and the production sector. Figure 2.1 shows the relationships among these four major sectors. Between each pair of sectors there are flows of information, and in some cases flows of dollars or physical capability. In this case the arrows represent the flows and the direction of the flows. The type of line used in the body of the arrow identifies the type of flow. Thus a dashed line indicates an information flow, a solid line denotes a physical flow, normally of capability, and the solid line with dollar signs indicates the flow of funds.

Beginning with the requirements/capability sector, information flows to and from the other three sectors. This flow provides information concerning the modification requirement to the development and production sectors. Information on the potential solution and its cost estimate then flows from those sectors back to the requirements/capability sector, and the solution information returns to the financial sector. Information about the success or failure of the request for required funds flows from the financial sector back to the requirements sector. The development sector receives information from the requirements/capa-

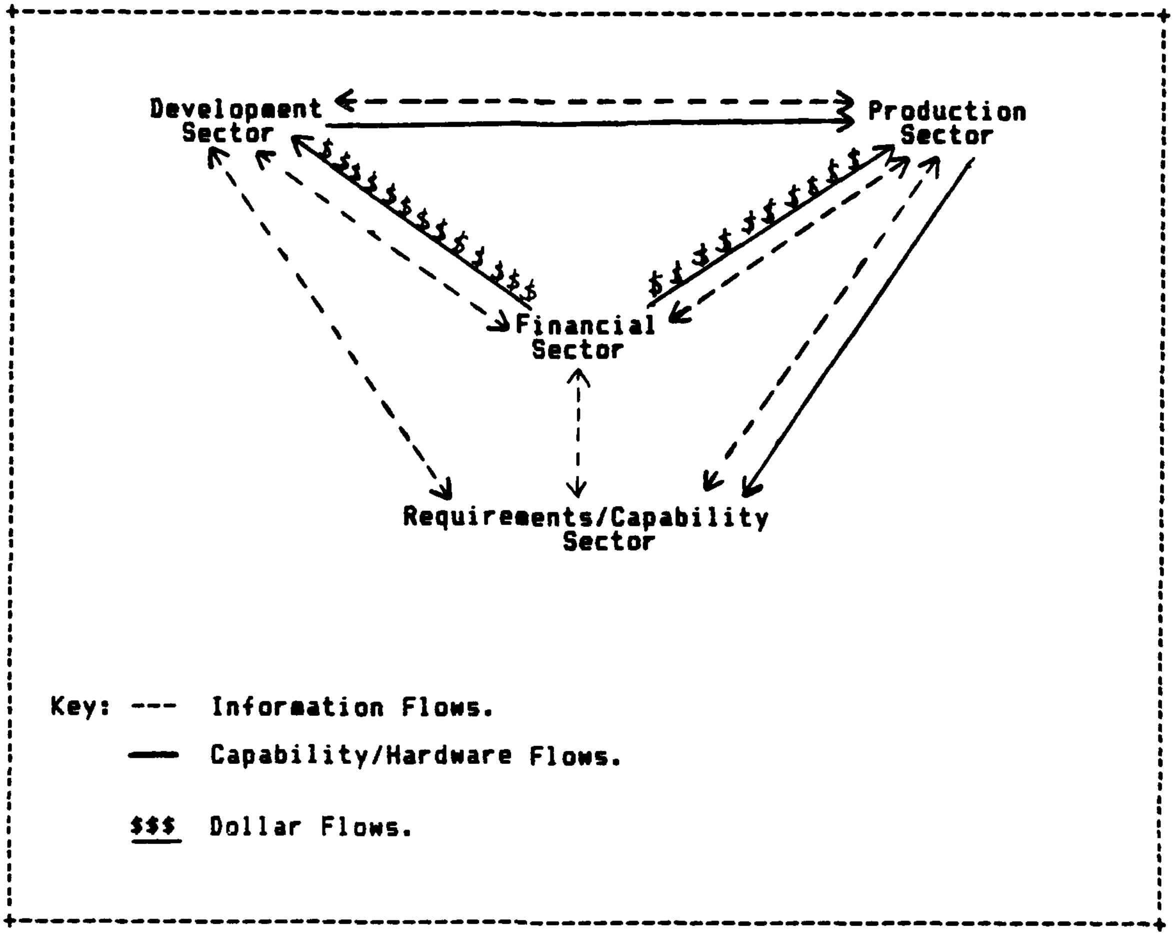


Fig. 2.1. Overall Sector Diagram

bility sector on the threat, returns solution and cost information to it and to the financial sector, receives financial information from the financial sector, and sends work results and design and cost information to the production sector. The development sector also transfers the developed hardware to the production sector, and receives dollars from the financial sector. The production sector receives information from all three sectors, hardware from the development sector, and dollars for production from the financial sector. Production hardware flows from the production sector to the requirements/capability sector, increasing capability and decreasing requirements. The financial, requirements/capability, and production sectors all have visibility into the information flows between each of the sectors as indicated by figure 2.1. The financial sector also controls all the money. This combination of information and money offers the financial sector the opportunity for great influence over the other sectors.

With the overview of the flows among the major sectors complete, discussion of the individual sectors and subsectors may proceed. Accompanying the discussion for each sector are diagrams which illustrate the relationships being considered. Reference to these diagrams will facilitate understanding of the model during its development.

Requirements/Capability Sector

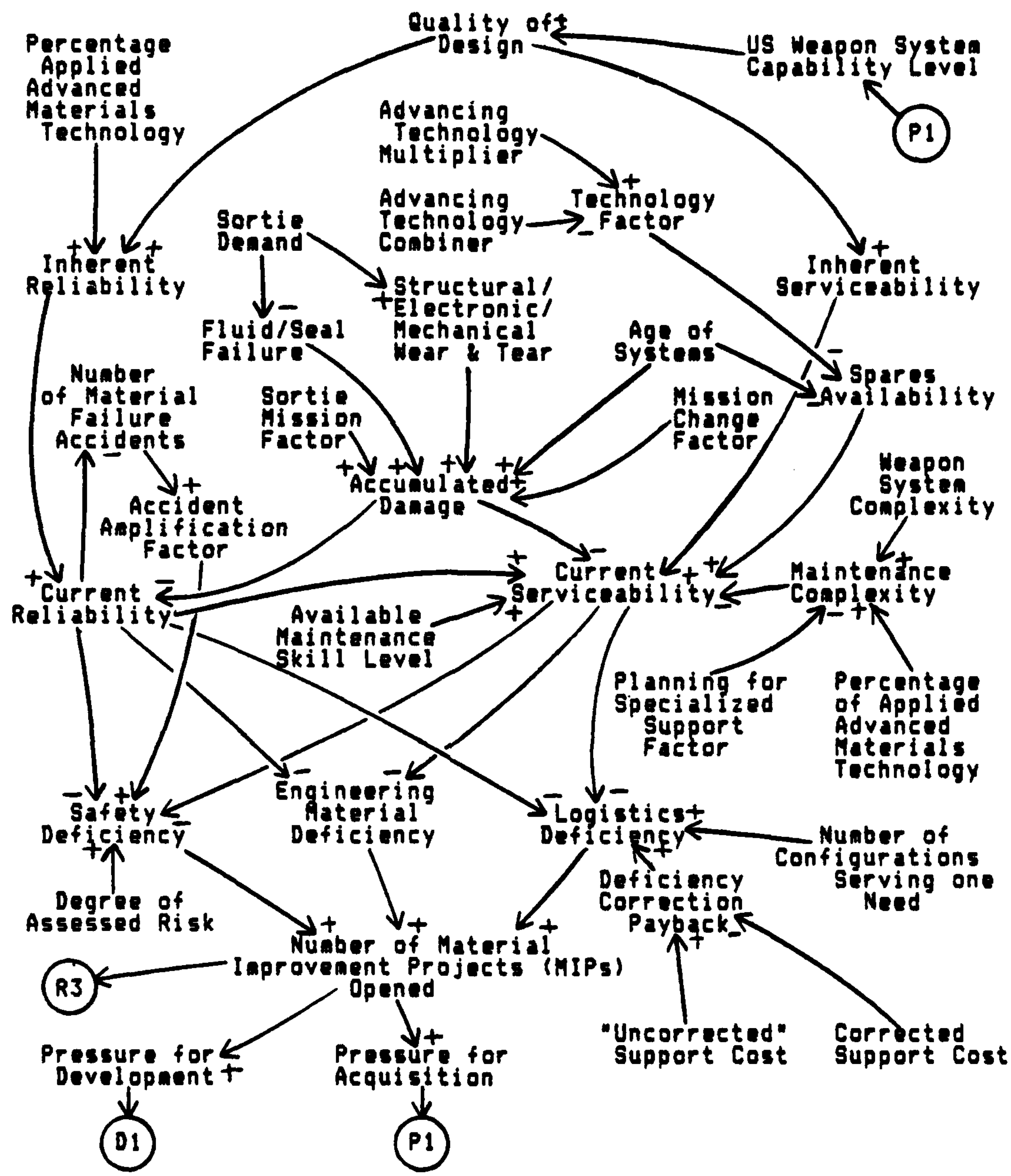
With the requirements/capability sector begins discussion of the aircraft modification process in terms of the causal loop diagrams described earlier. While modifications are generally thought of as beginning with the requirement, in reality the process is a giant loop. Requirements develop on a continous basis. Modification programs are initiated and carried forward to satisfy these requirements. At some time in the future, modifications to satisfy these requirements are completed and in return reduce the original requirements. During this process, however, other requirements have developed and other modifications are in progress forming a complete loop. It is simply for the sake of convenience that the discussion begins in the requirements/capability sector. This sector contains the development and approval of the requirements for Class IV and Class V modifications.

Within the requirements/capability sector there are four subsectors. The Class IV requirements subsector discusses the development of the deficiencies that lead to a Class IV modification. The Class IV approval subsector takes the modification requirement resulting from the previous subsector through the approval process. The Class V requirements subsector discusses the development of the Class V modification requirement, and the Class V approval subsector takes that requirement through the Class V

approval process. The result of both approval processes is pressure for development and acquisition and the creation of program decision packages (PDPs) for consideration in the financial sector. Discussion of the four subsectors of the requirements/capability sector is expanded below.

<u>Class IV Requirements/Capability Subsector</u>. In the Class IV requirements/capability subsector, the requirements for Class IV modifications grow from the deficiencies of operational aircraft. The development of the deficiencies and their transformation into requirements is presented in this sector.

The development of the Class IV modification requirement begins with the existing US weapon system capability level (figure 2.2). In recent years, the emphasis for new weapon systems has been on quality rather than quantity. In this usage, therefore, an increase in the U.S. weapon system capability level increases the quality of the design. Mr. Grover Dunn (Deputy Chief, Aircraft Systems Division, Directorate of Maintenance and Supply under the DCS for Logistics and Engineering at HQ USAF) stated that reliability and serviceability are inherent in the quality of the design of any weapon system (23). Thus quality of design explicitly means design style or emphasis that results in some level of reliability and serviceability. Serviceability means the degree of ease with which a system can be supported and includes accessibility of subsystems,



Key: R3 - To the Class IV Requirements Approval Subsector.
P1 - From the Production Sector.
D1 - To the Development Sector.

Fig. 2.2. Class IV Requirements/Capability Subsector (R1)

readability of technical orders, difficulty of training maintenance personnel, availability of spare parts, and utility of test equipment (and its reliability as well), among others. It is influenced by available maintenance skill levels, complexity of both the weapon system and the maintenance approach, application of advanced technologies such as composite materials, and the degree of planning for specialized support for these complexities and advanced technology.

The inherent reliability and serviceability result from the original design, or current design, of the system. For example, the B-52 was designed originally to fly at very high altitudes; associated with that design, whether conscious or not, was a design reliability and serviceability. The usage of a weapon system changes as the threat changes, the mission changes, or the anticipated theater of operations changes. When the use of a system changes, so also do the stresses placed on the system, and the way that, therefore, system reliability behaves. The difference between the designed-for use of a system and its current use is evident in the current reliability and therefore, the current serviceability of the system. In other words, the difference between the current reliability and the inherent reliability is the result of the change in usage, as captured in the variable accumulated damage. Returning to the example of the B-52, its mission today

requires flying very close to the ground. This kind of flying places much greater stress on wing structures and engines; therefore they age—or show the accumulated damage—much more quickly than had they stayed with the high altitude mission.

In consideration of these factors, the diagram (figure 2.2) may be read as follows. As the quality of design increases, the inherent reliability of the system increases, as does the inherent serviceability. The application of advanced materials technology in the system causes an additional increase in inherent reliability. As inherent reliability increases, current reliability increases. Current reliability is decreased, however, by an increase in accumulated damage. Accumulated damage increases as a consequence of a variety of variables. As mentioned above, a change in or addition to the basic mission of the aircraft will change the rate at which damage is accumulated. Thus as the mission change factor increases, the accumulated damage increases. For another example, sortie demand has been shown to affect accumulated damage, but in opposite directions. An increase in structural, electronic, and mechanical wear and tear can be logically expected from increased sorties. At the same time, however, certain systems seem to improve their reliability with increased use, and actually degrade with decreased use. Hydraulic systems are a classic case. Interviewees

(23; 36; 51) have said that depots frequently see aircraft that worked perfectly when they came in for periodic depot maintenance, but "leaked like sieves" (36) after a five or six week nonoperational period. Seals in fluid systems work better when they are used. Returning to the diagram, as sortie demand increases, fluid/seal failures tend to decrease, but structural, electronic, and mechanical wear and tear increases. As fluid/seal failures increase, accumulated damage increases. Similarly, as wear and tear on other systems increases, accumulated damage increases.

Age, as it increases, is another factor which increases accumulated damage. Some components of aircraft lose resilience or elasticity simply as a matter of years of existence. Stress is not involved. Others accumulate stress in the form of vibration, twisting, temperature changes, and so forth, as the aircraft ages, whether the specific component is used or not. Finally, different sorties cause damage to be accumulated at a greater rate than others. This factor is different from the mission change factor discussed earlier. The mission change factor recognizes changes to or additions to the basic mission or missions of the aircraft--an external change. In this case different sorties within the current mission structure--an internal change--affect the rate of damage accumulation. The RF-4, for example, flies relatively nonwearing missions, generally straight and level, with very little time spent at

high G's. The F-4, on the other hand, flies typical combat training missions, with high G forces, and other maneuvers close to the edge of the flying envelope. Modifications to replace fatigued structural elements must be made two to three years earlier in the life of an F-4 than an RF-4 (36). To represent this element of mission type there is a sortie mission factor. As this factor increases, accumulated damage increases.

Age also affects the availability of spares for the various aircraft systems. As an aircraft gets older, the vendors and subsystem contractors who originally supplied spares either disappear (go out of business or change fields) or choose to stop making the parts or subsystems used in the aircraft (36; 51). Spares availability is also decreased by a technology factor, which tends to work on the contractors and vendors mentioned above. As the technology in a particular field advances, it can have one of two different effects on an existing part producer.

On the one hand, if a vendor has gone out of business, and is to be replaced, there is a technology multiplier effect. This means that replacing one part with a new vendor's part will require one or more additional changes because the advancing technology of the new part is not compatible with the older technology in the system. For example, replacing a tube radio with an integrated circuit radio provides a smaller, more reliable radio. On an old

aircraft, however, like a C-123, it may not work at all, because the power provided by the aircraft is not "clean." Peaks in the power supplied may cause the new, sensitive radio to burn out. Thus a new power supply may be required--which may then require new wiring, or cooling--and so it goes. In other words, the advancing technology multiplier, as it increases, increases the technology factor, which in turn tends to decrease spares availability.

On the other hand, there is an advancing technology combiner effect, which by replacing several obsolete parts with one more reliable, cheaper part tends to decrease the technology factor. This in turn increases spares availability. The existence of these technology effects has been generally agreed to (23; 36; 49; 51).

An increase in spares availability increases current serviceability. An increase in accumulated damage tends to decrease current serviceability directly as it increases the work load in both type and number of repairs. The increase in accumulated damage indirectly affects current serviceability as it decreases current reliability. An increase (decrease) in current reliability increases (decreases) current serviceability by, again, increasing (decreasing) the load of work on the maintenance system. It also tends to use up the supplies and parts in the logistics pipeline, since when reliability decreases, parts must be replaced more frequently.

Current serviceability is also influenced by the maintenance complexity of the system. Maintenance complexity derives from the complexity of the basic weapon system, the percent of applied advanced materials technology in the system and how much planning for the required specialized support was done to offset the complexity. Weapon system complexity as it applies to maintenance complexity results from the planning done by the designers in the initial development of the system. Older systems, while less complex in their subsystems and basic design, were not specifically designed for maintenance. Yet, since the basic design was relatively simple, the maintenance complexity is relatively low.

In the most modern systems, the design philosophy required consideration of maintainability from the beginning of concept validation (19:2). For those systems designed between the time technical complexity began to complicate designs and the time that specifically designing for maintainability was required, maintenance complexity is very high. The result is demonstrated by horror stories such as the design that located the low reliability radio under the high reliability ejection seat of the F-4. That meant that every time the radio breaks (frequently) the ejection seat has to be removed to get to the radio--which caused the reliability of the seat to drop dramatically, and therefore increase the frequency of maintenance on both

subsystems. An increase in the complexity of maintenance resulted not only from the inaccessibility of the radio, but also from the fact that removing the ejection seat required involvement with the explosive charges that propelled the seat. In 1977, Lt Gen Bryce Poe said that over 58,000 manhours per month are used to remove these seats to get to broken radios (40:60). Thus an increase in weapon system complexity causes an increase in maintenance complexity, all other things equal.

The percent of applied advanced materials technology, such as composites in wing structures, causes an increase in maintenance complexity as it increases. This occurs because working with composites and other advanced material technologies requires much more controlled and sophisticated procedures than the old better-known materials. The advanced materials are more reliable, but once they are damaged, the repair task is complex. However, system complexity and maintenance complexity resulting from advanced materials can be offset by sufficient planning for the specialized support they require. Thus an increase in planning for specialized support causes maintenance complexity to decrease (48).

An increase in maintenance complexity decreases current serviceability. This increase in complexity can be at least partially offset by an increase in the maintenance skill levels available to work on the system. Retention of

experienced maintenance people, and acquisition of qualified recruits has been an issue much discussed and studied in recent years (24; 34). To capture this effect, the level of available maintenance skills is used. An increase in this level causes an increase in current serviceability.

It can be seen that current serviceability is distinguished from inherent serviceability by accumulated damage, spares availability, maintenance complexity, available maintenance skill levels, and current reliability. From current serviceability and current reliability come the accumulations of deficiencies that result in the number of material improvement projects (MIPs). As each of current serviceability and reliability increase (decrease), the numbers of safety deficiencies (Class IVA), engineering material deficiencies (Class IVB), and logistics deficiencies (Class IVC) decrease (increase).

In the world of Class IV modifications there is a hierarchy of the modifications that depends on the classification into which a particular modification falls. Modifications to correct safety deficiencies, have the highest priority. If a proposed modification can be associated with resolving a hazard to crew members, maintenance personnel, or equipment, it enjoys a much higher probability of being approved and funded, than do other types (36; 44; 41). Second in the priority ranking are those termed engineering material deficiencies—otherwise thought of as

mission degrading deficiencies. Any reliability or serviceability deficiencies that impair performance of the mission are categorized here as Class IVB modifications 4nd are funded after safety deficiencies. Last in the hierarchy is the category of logistics deficiencies. These deficiencies are associated with the cost of supporting a system. While their priority is last in the trio of classes, the benefits of these modifications are found in reduced costs to the Air Force of supporting the system. These categories are not mutually exclusive. A modification to eliminate a safety deficiency also may reduce support costs significantly. For this reason both reliability and serviceability influence all three types of deficiencies.

Current reliability also influences accident rates. Two types of accident causes are generally listed: pilot error, and material failure. Only the material failure accidents are considered here. A failure of a part obviously ends its reliability. Reliability is measured by the number of failures divided by the number of operating hours. Thus, as current reliability increases (decreases), the number of material failure-caused accidents tends to decrease (increase). Obviously certain accidents are more serious than others. To fairly consider accidents, an accident amplification factor weights each accident according to its seriousness. As the number of accidents

increase, the factor increases; as it increases, the number of safety deficiencies increase.

Since safety deficiencies have the highest priority for funding, naturally that category is preferred for any highly desired modification proposal. To reduce this tendency, and to document the degree of risk to people and equipment, approval of a safety deficiency for modification requires completion of a risk assessment (2). This assessment considers all circumstances involved in the recorded deficiencies to determine the degree of risk associated with the deficiency. An increase in the degree of assessed risk causes the safety deficiencies to increase. Then, of course, an increase in safety deficiencies causes the number of (MIPs) opened to increase.

Engineering material deficiencies are only influenced by reliability and serviceability. As current reliability increases (decreases), or as current serviceability increases (decreases), engineering material deficiencies decrease (increase). As these deficiencies increase, again the number of MIPs opened increases.

Logistics deficiencies react in the same way to current reliability and current serviceability. Logistics deficiencies are also influenced by the payback associated with correction of the deficiency and by the number of configurations serving one need. As discussed earlier, logistics deficiencies originate from logistic support problems that

are not safety related or mission-degrading, but which cost the Air Force too much to support, or are impossible to support because parts are no longer available.

One source of this problem results from having many configurations of a system all serving one need. An example might be an aircraft type that carries six different radar types, all performing the same mission at approximately the same level of performance. The mission is accomplished by all the radars, but the supply organization must carry spares and parts for all six configurations, the maintenance organization must train people to work on each of the six, and documentation must be maintained on all six. At the field level, maintenance test equipment, possibly unique to each, must be supported, and at the depot level, aircraft must be handled differently for periodic maintenance. Eventually the strain on the system becomes so significant that modification to reduce or eliminate the multiple configurations becomes worthwhile. Therefore as the number of configurations serving one need increase, the logistics deficiencies also increase.

Associated closely with this is the payback concept. Multiple configurations, or unconventional support systems cost the Air Force more to support than do single configurations or conventionally supportable systems. As the cost of supporting "uncorrected" problems increases, the poten-

tial for or actual payback from correcting the deficiency increases. Similarly, the life cycle support cost of a modified system, including the cost of the modification, could be substantially lower than the unmodified system, even without multiple configurations or difficult support cases. As this "corrected" support cost increases (decreases), the deficiency correction payback decreases (increases). Thus the difference between the uncorrected and corrected support costs forms the deficiency correction payback of the modification. Such a payback analysis is required with the submittal of any Class IVC modification proposal (36). As the value of the payback from correcting a problem increases, the level of logistics deficiencies increases. And, as that level increases, the number of MIPs opened increases.

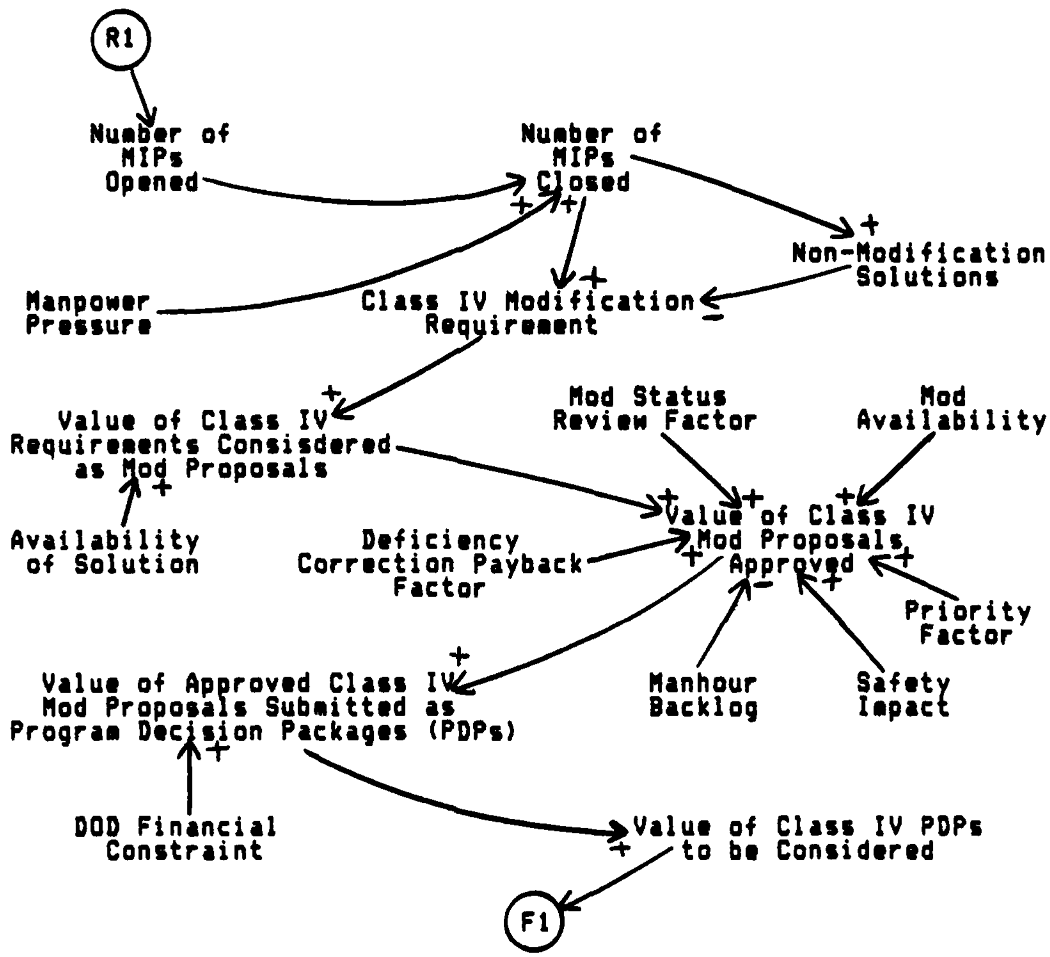
The number of MIPs opened collects all the deficiencies that reach some "threshold of pain" (36) felt by system or item managers. Since there is no formal determination of this threshold, it is totally dependent on the interest expressed by the user, the system manager or the item manager. As one result, the modifications proposed through the system tend to depend on the experience, judgement, and personality of the managers involved (23; 36; 48).

Opening a MIP begins a pressure to close the MIP. Closing a MIP can only occur when a solution to the deficiency has been found and accepted by the configuration control

board (CCB). Therefore, closing a MIP creates a Class IV modification requirement. There is pressure to close MIPs for two reasons. The first is that no funding will be approved without a solution to the deficiency in hand. The second derives from the fact that the number of engineering and technician positions approved for working on MIPs depends on the number of MIPs closed during a quarter. The result is pressure for development (if required) or acquisition of a solution that increases as the number of MIPs opened increases. There is also an increase in MIPs closed, as the number opened increases (see the Class IV approval subsector shown in figure 2.3). The number of MIPs opened ends this subsector and begins the next.

Class IV Approval Subsector. In the Class IV approval subsector (figure 2.3) the requirements for Class IV modifications are reviewed for potential entry into the competition for funding. The Air Logistics Centers (ALC) prepare all the potential modifications for the review process. According to the interviewees (36; 51), there are approximately 5,000 potential Class IV modifications reviewed each year. Each represents a new start modification. Ongoing modifications (funded) are not resubmitted as modifications.

When the ALCs are ready, analysts from HQ AFLC and HQ USAF travel to each ALC to review every modification proposal for its reasonableness and its readiness to



Key: R1 - From the Class IV Requirements/Capability Subsector.
F1 - To the Air Force Finanacial Subsector.

Fig. 2.3. Class IV Requirements Approval Subsector (R3)

proceed into implementation. This review is really the only requirements review most Class IV modifications receive. Those proposals which repair safety deficiencies, or which the using command strongly supports, or for which solutions are in hand tend to get approved. Problems that are not related to safety, and for which no solution is apparent tend to get deferred, regardless of the problem's seriousness, pervasiveness, or cost to the logistics system. This review of requirements does not consider whether the problem establishes a requirement. It only determines whether a proposed solution will resolve a real requirement. There appears to be no system for identifying and addressing difficult problems in this category. Currently the ALCs rely on their own engineers or on the aircraft contractor to figure out a solution and if necessary, propose the modification.

The modification status review does not examine whether the modifications that are ready to proceed are the most reasonable or most important ones, nor does it consider whether the new modifications are compatible with past, ongoing, and known future modifications to the same aircraft system. As a result, sometimes there are modifications approved to enter the funding process that are later dropped due to incompatibility with the aircraft configuration, or because the problem had already been fixed as part of an earlier modification (36; 51).

Once a modification proposal is approved to enter the funding process, it is sent from the ALCs to HQ AFLC. At AFLC all the modifications are coded for priority ranking by a computer model. The model considers three major categories of sixteen factors for each modification proposed, and weights factors according to their importance in the overall list of factors. The values of all the factors are then added together to assign a priority index to each modification (17).

The three categories of factors used by the AFLC model are priority, availability, and payback. The greatest amount of weight is assigned to factors in the priority category, then to factors in the availability category, and finally to factors in the payback category. The priority category considers the class of the modification (safety, mission degrading, or logistics), the status of the modification (whether firm, tentative, or only budgetary), logistics support priority (seriousness of the support problem), and some other ranking factors assigned by maintenance and logistics managers. The availability category considers how far the solution to the problem has progressed. If the modification proposal is in the form of an engineering change proposal (ECP) only, it receives a weight of one. If it has also gone through contract award, trial installation, and kit-proofing, it receives an additional weight of one for each step. Thus, the more locked in a single

solution is at review time, the higher the priority it will enjoy in the ranking process. The manhour backlog at the depot also is considered in this category. It reduces the final index according to what the size of the backlog of modifications is at the depot where the mod would be installed. The last category, payback, considers the logistics support cost rate of return on dollar invested values, amortization of the modification cost, fuel savings, and projected improvements in time between maintenance actions and reliability (17).

The result of the computer priority model is a rank ordered listing of all the modification proposals which were submitted to AFLC. This listing is then reviewed by AFLC managers to ensure that the ranking reflects the true desires of AFLC and Air Force headquarters staff. Once the listing is complete, a financial constraint is applied.

The financial constraint represents the amount of funds AFLC had submitted as the second year of the previous year's budget request. This amount is returned by DOD to USAF and then to AFLC as the interim financial constraint against which AFLC should program the next year's modifications. Not all modification proposals submitted each year can be funded. Those which achieve a high index number from the priority model, and thus rank high in the final list, will be funded in this first cut. The cutoff is by dollars, so the exact number of modifications funded in any one year changes (36).

The modification proposals in the funded portion of the list are then formed into program decision packages (PDPs). The large modification proposals are placed in individual PDPs to allow their consideration separately from the others (such as the F/FB-111 Avionics Improvement Program). The rest of the modifications are combined into one large PDP known as the Class IV Mod PDP. The total value of the Class IV PDPs is then submitted to the Air Staff for continuation in the Planning, Programming, and Budgeting System (PPBS).

As shown in figure 2.3, the Class IV approval subsector begins with the number of MIPs opened input from the requirements development process. As indicated in the last section, an increase in the number of MIPs opened increases the number of MIPs closed. An increase in manpower pressure further increases the number of MIPs closed. An increase in MIPs closed causes an increase in Class IV modification requirements, which are then considered as modification proposals. The value of those proposals is increased as the availability of solutions to deficiencies increases, and as the level of Class IV requirements increases.

Not all deficiencies are best resolved by modifications. In some cases changes in procedures, addition of inspections, changes to technical orders, or changes in missions can solve the problem. The other-than-modifica-

tion solutions are increased as the number of MIPs closed increases. As these other-than-modification solutions increase, the level of Class IV modification requirements decreases.

As the value of Class IV requirements considered as modification proposals increases, the value of Class IV modification proposals approved increases. As was described previously, the modification status review approves the proposals, and the computer priority model weighs the effects of priority, availability, and payback to result in a total value of approved proposals in the form of the priority list. Therefore, as the mod status review factor, the mod availability, the priority factor, the safety impact, and the payback expected from the modification each increase, the value of the approved proposals increases. The only factor which can decrease this value is the manhour backlog in the depots, which may have a small negative value. Essentially, as the manhour backlog increases, the value of approved proposals decreases. As the value of approved Class IV modification proposals increases, the value of approved Class IV modification proposals submitted as PDPs increases, subject to the DOD financial constraint. As the financial constraint increases, so also the value of PDPs submitted increases (the cutoff line moves farther down the priority list).

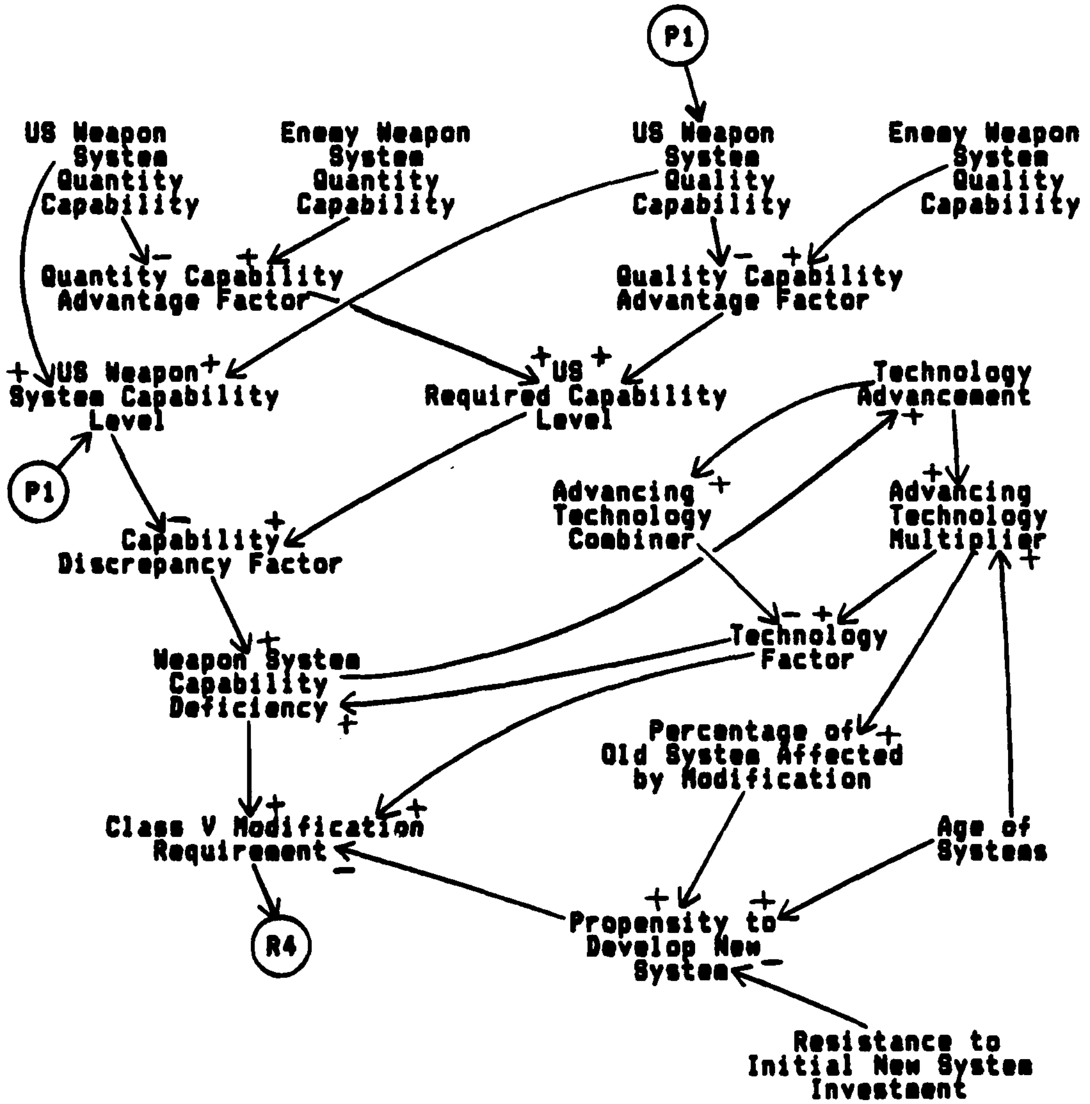
The value of the PDPs submitted to the Air Force funding process leaves this subsector and moves to the Air Force financial subsector. The Air Force financial subsector, whose discussion follows the Class V requirements/capability subsector and the Class V approval subsector, will combine the PDPs generated here and in the Class V approval subsector.

Class V Requirements/Capability Subsector. Recall from the definition of Class V modifications presented in chapter I, that a Class V modification changes the mission capability of the present system configuration through the installation or removal of equipment. This change in configuration takes place to meet a new or changing enemy threat. The Class V requirements/capability subsector captures the development of a requirement for a Class V modification.

The Class V requirements/capability subsector begins with some level of U.S. weapon system quantity capability and quality capability. These two types of capability levels are compared against enemy capabilities to result in a discrepancy level (a device which allows advantages, or pluses, and disadvantages, or minuses to be accumulated to show net status). The discrepancy plus the effects of technology lead to a level of Class V requirements, which then enters the Class V approval process for consideration.

Discussions of the threat from potential enemies have in recent years dealt not only with the number of systems the enemy has (fighters, bombers, munitions), but also the quality of each system in comparison with those in U.S. forces. Such terms as quality advantage and quantity advantage can be used to describe the comparisons at any point in time. Measurement of quality is significantly more difficult than counting quantities, but the attempt is made at least in descriptive terms.

On the diagram in figure 2.4, then, as U.S. weapon system quality increases, the quality capability advantage factor decreases. The quality advantage factor, which is set up to illustrate the advantage the enemy has over the U.S., is increased by an increase in enemy weapon system quality capability. Similarly, there are quantity capabilities of the U.S. and the enemy which feed into a quantity advantage factor. As the enemy weapon system quantity capability increases, the quantity advantage factor increases. As the U.S. quantity increases, the quantity advantage factor decreases. As the advantages of quality and quantity the enemy enjoys over the U.S. increase, they cause increases in the required level of U.S. weapon system capability. The increase in U.S. weapon system quality and quantity also increase the U.S. weapon system capability level. This level collects the increases (or decreases) in U.S. quality and quantity to arrive at a



Key: P1 - From the Production Sector.
R4 - To the Class V Approval Subsector.

Fig. 2.4. Class V Requirements/Capability Subsector (R2)

net capability of U.S. defenses. The required level of U.S. capability and the actual level of U.S. capability are then combined to form the capability discrepancy factor. As the former increases, the discrepancy increases. As the latter increases, the discrepancy decreases. Finally, as the discrepancy increases, the level of weapon system capability deficiencies increase.

The deficiencies in weapon system capabilities tend to drive the pursuit of, and eventually the advancement of technology, as the U.S. tries to resolve its deficiencies. As technology advances, it creates an effect similar to that seen in the Class IV requirements/capability subsector. On the one hand, the advancement of technology allows for the addition of capability in a way that minimizes the impact on the basic system, the combiner effect. For example, as technology advanced from tubes to transistors to integrated circuits the size of components decreased so much that several new subsystems could fit into the space left by removing one older subsystem. The same example can illustrate the other effect of technology, that of multiplying the required changes. Those same advanced components that took up less space required more sophisticated power supplies, more efficient cooling systems, and frequently, access to the aircraft's computer. If the aircraft had no computer, then a simple replacement could cause the replacement of much of the

original avionics suite. These two effects are combined in the technology factor, which increases as the multiplier increases, and decreases as the combiner increases. As the technology factor increases, it increases both the weapon system capability deficiencies and the level of Class V modification requirements.

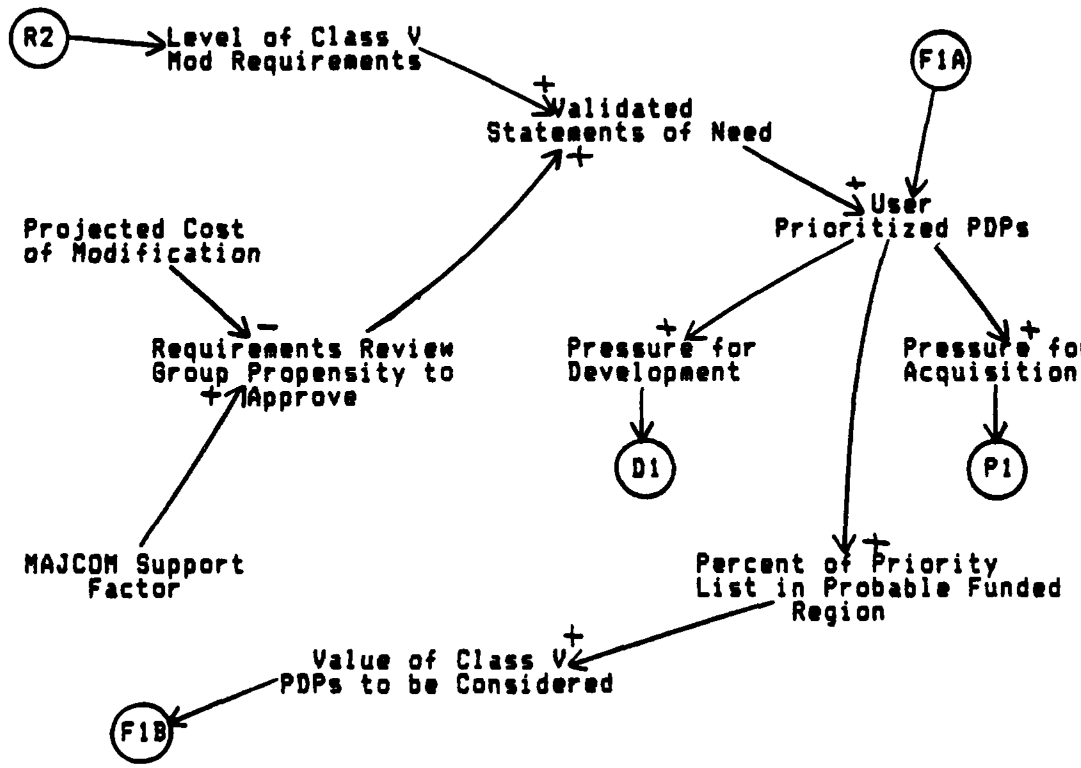
Clearly the multiplier effect increases the percent of the old system affected by modifications. As that percent increases, it tends to increase the propensity of the manager to prefer to develop a new system to replace the old. This propensity is further increased as the age of the system increases. Increasing age also tends to increase the advancing technology multiplier, as current technology gets further and further away from the technology incorporated into the basic weapon system. Resistance to the initial investment cost in dollars and time to develop a new system is found to decrease the propensity to develop a new system.

As the propensity to develop a new system increases, it causes a decrease in the level of Class V modification requirements. The level of Class V modification requirements is the connection between the Class V requirements-/capability subsector and the Class V approval subsector.

<u>Class V Approval Subsector</u>. In order for the Class V requirements to be funded, they must be validated and ranked in priority order. The Class V approval subsector describes this process.

The Class V approval subsector begins with an input level of Class V modification requirements. These requirements come to the Air Staff from the using commands in the form of Statements of Need (SONs), which then must be validated by the Requirements Review Group (RRG). The validated SONs are then ranked by the user's priority system, and returned to the Air Staff in the form of PDPs for entry into the PPBS.

Examination of the diagram (figure 2.5) reveals that as the level of Class V modification requirements increase, the number of validated SONs increases. The actual validation review normally approves all the requirements submitted by the using commands. The review process seems to concentrate on insuring that all the appropriate actions are completed, rather than actually pass judgement on requirements. The RRG propensity to approve depends on the support of the using Major Command (MAJCOM), and to some extent on the projected cost of the modification. As the MAJCOM support increases, the propensity to approve increases. As the projected cost increases, the propensity to approve decreases. This is somewhat misleading, however, since the group only sends SONs back if they are incomplete or insufficiently justified; both conditions result in resubmittals (51). As the propensity to approve increases, the validated SONs increase.



Key: R2 - From the Class V Requirements/Capability Subsector.
F1A - From the AF Financial Subsector.
F1B - To the AF Financial Subsector.
D1 - To the Development Sector.
P1 - To Production Sector.

Fig. 2.5. Class V Modification Approval Subsector (R4)

As the number of validated SONs increase, the number of SONs in the user's modification priority system increase. Each of the using commands has a system of its own for ranking its PDPs. The resulting list, without dollar constraints, is submitted to Air Staff for use in ranking the PDPs in the programming part of the PPBS. The result of the prioritizing at each command is a list, of which some percent will get funded. Of the funded part of the list, there is some further amount broken out which represents Class V modifications. At this point the value of Class V modifications expected to be funded passes from the Class V approval sector to the Air Force subsector of the financial sector.

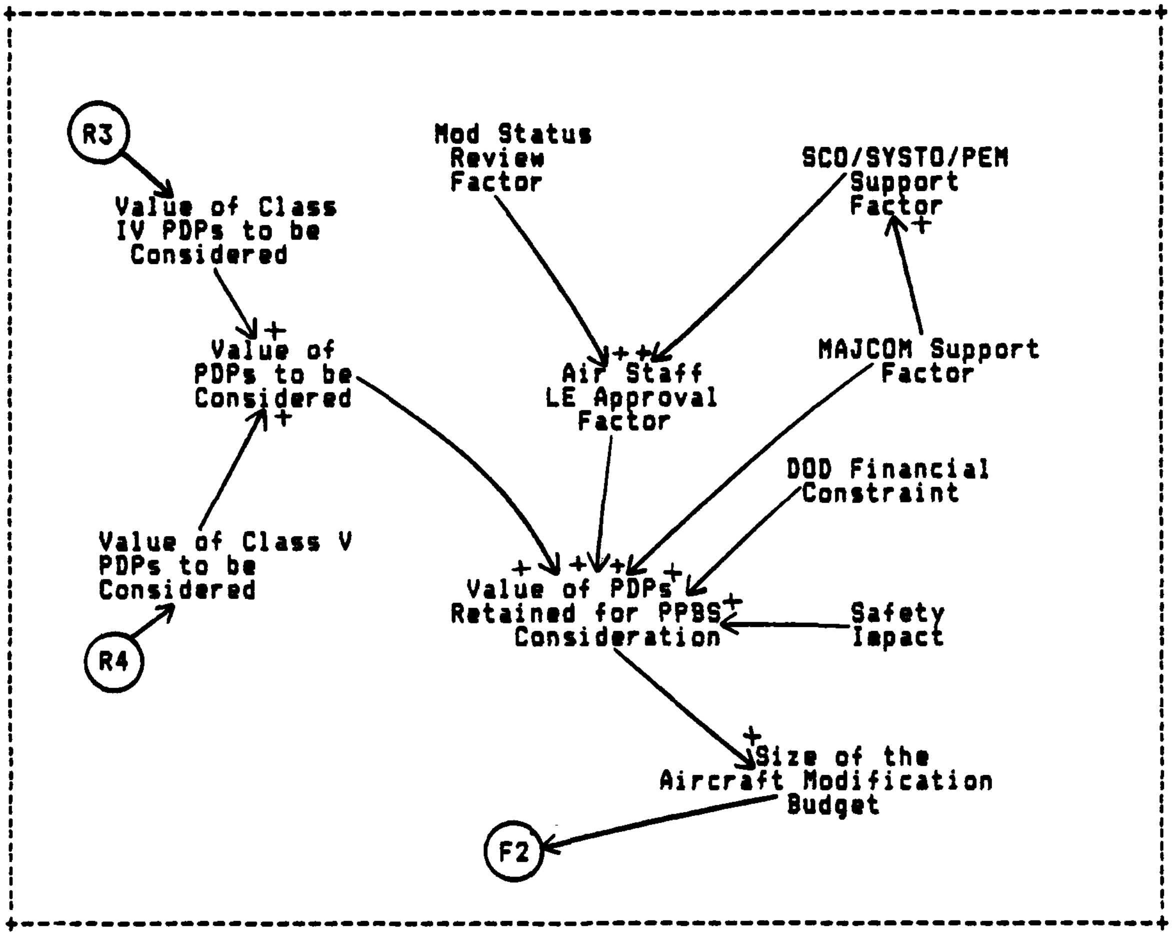
Financial Sector

The financial sector consists of three subsectors. Within these subsectors, the modification budget is developed through the PPBS, approved by DOD, and enacted into law by the Congress. The financial sector connects the requirements generation and approval process with the development and production sectors which satisfy the requirements. The results of the two approval subsectors of the requirements/capability sector enter the financial sector through the Air Force financial subsector. From this subsector the resulting size of the aircraft modification budget moves to the DOD financial subsector. Finally the aircraft modifications (as a percentage of the

President's Budget) leave the DOD financial subsector and enter the external financial subsector, where the Congress enacts the budget. The resulting approved funds move to the development and production sectors.

Air Force Financial Subsector. From the two requirements approval subsectors, the Air Force financial subsector receives PDPs for approved Class IV and Class V modifications. The Class V modifications generally have a PDP for each modification proposal, if the modification affects only one aircraft type. If more than one aircraft type is affected, there usually is one PDP for each weapon system. As discussed earlier, the Class IV modifications usually appear with a few single-system PDPs that are large, and one large PDP that may have several hundred small modifications included in it. The Class V modification PDPs and the large Class IV modification PDPs are considered individually for funding. In the Class IV Mod PDP, as it is commonly called, any modification over $.75 million is considered individually by the Air Staff, and sometimes by the DOD staff. The Class IV modification PDP is funded by Congress in a single lump sum with the rest of the mods in the PDP. Cuts in the Class IV modification PDP generally are by percent. That is, the entire PDP will lose perhaps ten percent, but HQ USAF or AFLC is free to decide what gets cut (36; 45; 51).

As figure 2.6 shows, the PDPs that enter the Air Force financial sector begin on a "to be considered" list. As the dollar value of PDPs exiting the approval processes increase, the dollar value of PDPs on the "to be considered" list also increases. Class IV PDPs retained for consideration in the PPBS process have already survived a rigorous review by the Air Staff, as was described in the Class IV requirements approval subsector. Before the PDPs are even prepared at AFLC the analysts from the Air Staff, together with analysts from AFLC, visit each of the ALCs and review every single modification being proposed that year. The Air Staff, therefore, has considerable knowledge of and impact on what is proposed for funding. As the modification status review factor (previously described in the Class IV requirements approval subsector) increases, it increases the Air Staff LE approval factor. The Air Staff LE approval factor is also increased by an increase in the SCO, SYSTO, or PEM support factor. A SCO is a system control officer at AFLC and a SYSTO is a systems officer at AFSC. Both act as staff focal points at their respective commands. A PEM, or Program Element Monitor, fulfills the same function in the Air Staff. These officers, as the project focal points at their respective staffs, can be very influential in getting attention, support, and funding for their projects. They, in turn, are influenced by the support for the system modification that is evidenced by



Key: R3 - From Class IV Approval Subsector.
R4 - From Class V Approval Subsector.
F2 - To DOD Financial Subsector.

Fig. 2.6. Air Force Financial Subsector (F1)

the major using command (MAJCOM support factor on the figure). As the MAJCOM support factor increases, the SCO/SYSTO/PEM support factor also increases.

As the value of the modification PDPs to be considered increases, the value of modification PDPs retained for consideration among all other programs in the funding process increases. Increases in MAJCOM support, in safety impact, and in the Air Staff approval factor all increase the value of PDPs retained. The total value of the modification PDPs retained is constrained by the interim DOD financial constraint. This constraint derives from the President's budget of the previous year, in which it is the value of the second year of the approved FYDP. In other words, if the FY86-90 FYDP had been approved, then in the FY87 Program Objectives Memorandum (POM) process the value of the interim DOD financial constraint for modifications would be derived from the dollar value for FY87 in that FYDP. Thus as the constraint increases, the value of PDPs retained increase. Finally, as the value of the PDPs retained increases, the size of the aircraft modification budget requested increases.

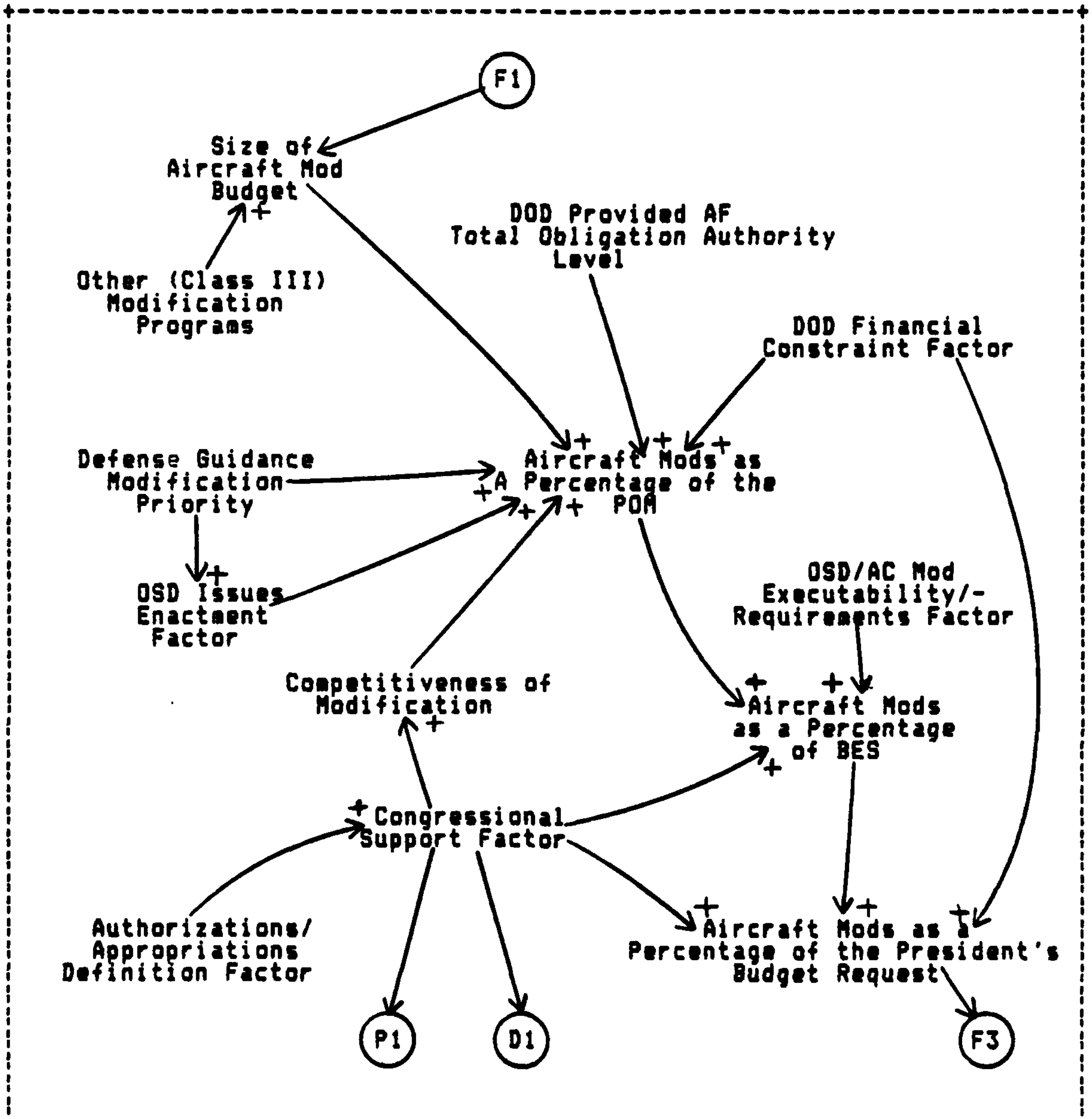
This process must be followed for every Class IV modification proposed, if it is to be funded. Class V modification proposals enter this process slightly differently. Any Class V modification requiring no development work and which is to be handled fully by AFLC follows nearly the

same process. A Class V modification that requires substantial development work, however, generally enters the financial system through AFSC. AFSC modification PDPs are considered in the same basic manner but in conjunction with all other programs, whether new acquisition, modification or basic research. Once the AFSC POM submission reaches the Air Staff, the development Class V modifications are considered with other development work. With the exception of the mod status review and the Air Staff LE approval factor, the Class V modification production PDPs follow the same path as the Class IV modification PDPs.

Once the size of the aircraft modification budget request is developed, it leaves the Air Force financial subsector and enters the DOD financial subsector.

DOD Financial Subsector. In the DOD financial subsector, the aircraft modification budget request is considered in the DOD PPBS for funding. This funding process is described in this section.

The DOD financial subsector (figure 2.7) begins with the size of aircraft mod budget request, which originated in the Air Force financial subsector. This variable includes all Class IV new starts, and Class V modifications which are budgeted for production. Class V modifications which are in the stages of development too early to budget for production are not included. That is, development dollars generally are not included in the "Mod Budget."



Key: F1 - From AF Financial Subsector.
F3 - To External Financial Subsector.
D1 - To the Development Sector.
P1 - To the Production Sector.

Fig. 2.7. DOD Financial Subsector (F2)

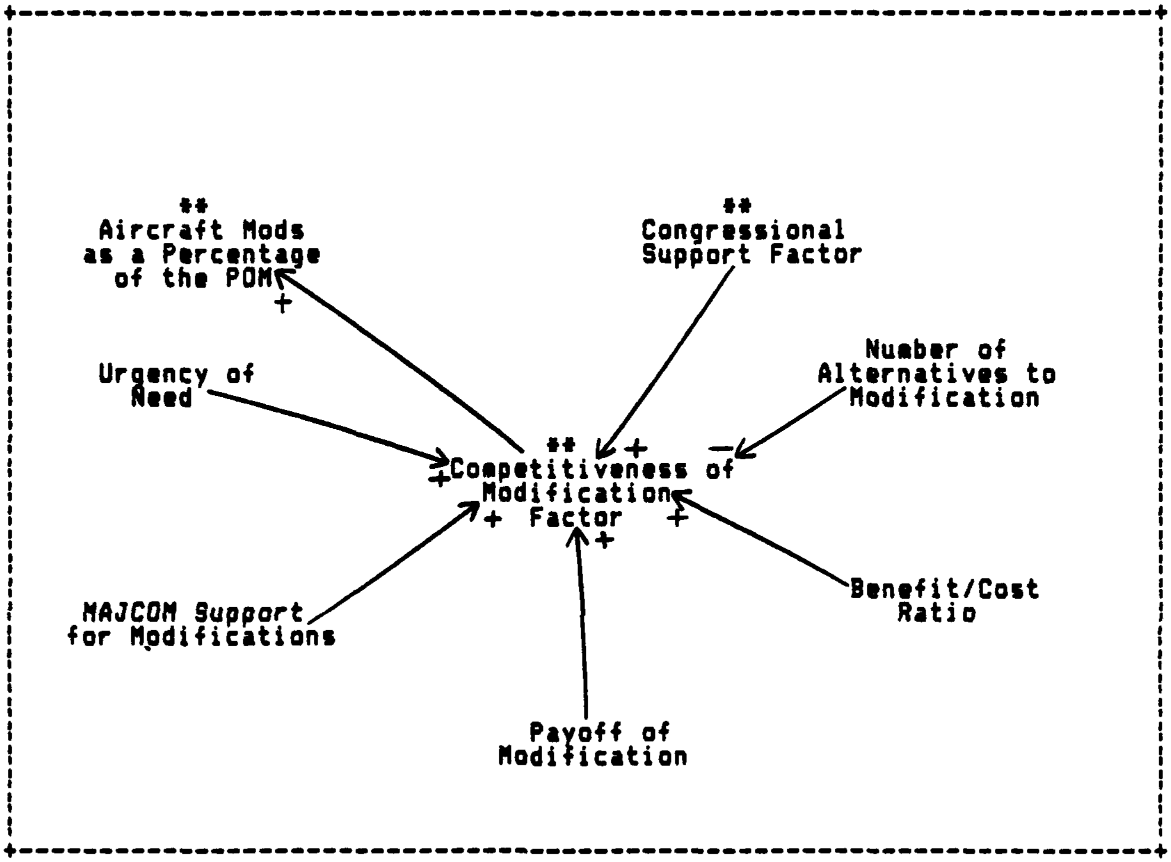
Also, once a Class IV modification is approved and funded, it normally reverts to the major weapon system budget line, and is never specifically examined alone again. The size of the aircraft mod budget request is increased by an increase in Class III modifications (modifications undertaken to a system while on the production line).

As the size of the aircraft mod budget request increases, aircraft mods as a percent of the POM increase. This variable also increases as the DOD-provided Air Force Total Obligation Authority (TOA) level increases. The AF TOA is a proposed level of funding provided by DOD to the AF as part of the annual Defense Guidance (DG). All this really means is that as the total number of dollars expected increase, the number of those dollars applied to modifications as a percent of total budget also will increase. Similarly, there seems to be a relationship between the tightness of the budget constraint and the percent of the budget applied to modifications. As the constraint gets tighter, the percent of the POM devoted to aircraft mods tends to increase. Interviewees suggested that this may be a reaction to major cuts in new acquisition programs in the belief that more capability can be bought for fewer dollars and in less time if existing aircraft are modified rather than replaced (46; 51). Thus, as constraints get tighter, more dollars are diverted from acquisition programs to fund modification programs. It was not obvious that this

relationship is as clear as described here. As financial constraints have become a way of life for DOD, an increase in the total dollars for modifications and an increase in the percent of the AF budget devoted to modifications have both been observed over the last five years.

The DG contains, at the strategic level, a priority ranking of plans and programs. Its basic guidelines are used to determine the priorities of individual programs in the POM. As specific modifications or modifications in general receive higher priority, modifications as a percent of the POM tend to increase. Additionally, as that priority increases, the likelihood of an OSD issue during the issue cycle of the POM process increases. If, for example, the DG had emphasized reliability modifications over all other programs, and the Air Force failed to propose important reliability improvement programs to be funded in the POM, then the DOD would raise an issue with that choice. As the DG priority factor increases, it serves to increase the percent of aircraft modifications in the POM. Finally, the competitiveness of modifications tends to increase the percent of aircraft modifications as a percent of the POM as competitiveness increases.

The competitiveness of modification factor (shown in figure 2.8) is composed of several other factors, some of which have already been seen. One such is the level of MAJCOM support for the modification. If the level of



Key: ** - Variables that appear in the DOD Financial Subsector.

Fig. 2.8. Factor Expansion of DOD Financial Subsector (F4)

support is high or increases, the competitiveness factor also is high or increases. Another familiar factor is the urgency of need. This factor, while fairly self-explanatory, represents both the priority of the weapon system on which the modification will be installed and the severity of the problem solved by the modification. As that urgency increases, the competitiveness of the modification increases.

Another factor is the Congressional support factor, which appears in the diagram of figure 2.7 as well as in the DOD financial subsector, the development sector, and the production sector diagrams. This factor indicates the effect of time and changing environments on the support the Congress gives for a particular modification. As the Air Force and DOD move through the POM, Budget Estimate Submittal (BES), and President's Budget process for any year (for example, 1986), the Congress at the same time is moving through the First and Second Concurrent Resolutions, the Authorization Bill, and the Appropriations Bill for the previous year (in this example, 1985). During the Congressional process, programs, including modification programs, get varying degrees of support. This support can range from so little that complete elimination from the budget occurs, to so much support that additions to the budget beyond the original DOD request are provided. A well-known example of the latter situation occurred every

year until 1984. Congress would fund more A-10 aircraft than the Air Force had requested. The direction of the support (subtractions versus additions) can vary during the process. As time passes, however, the direction and amount of change becomes more firm. As these changes become more solid, the effect of the changes on the next year's budget request becomes more pronounced. For example, suppose a program about to enter production had $15 million requested for it in the first year of production to build two aircraft, and $50 million the second year to build twenty-five aircraft. If Congress cut the first year request to $5 million, the work associated with the missing $10 million must be deferred. Equally, the money required to do that work must reenter the budget at some time to complete the required work. Early in the Congressional review cycle, DOD tends not to react to changes, because so little definition or firmness exists. Later, however, DOD will make substantial changes in the upcoming budget request in reaction to Congressional changes. This Congressional support factor converts the element of definition, called the authorization/appropriation definition factor, into a representation of support for a modification or modifications. As the Congressional support for a modification increases, the competitiveness of the modification increases.

In some cases, there are alternative solutions to deficiencies that do not require modifications. These might involve acquisition of a new system, changes in operating procedures, or even changes in strategy. As the number of reasonable alternatives to modification increase, the competitiveness of the modification decreases.

Any modification obviously involves some cost. Most provide a payback in the form of elimination of a deficiency, or in terms of greater reliability, fewer maintenance hours, cheaper parts, or fewer parts required. Two measures of payback are considered to be influences on competitiveness. The first, payoff of the modification, measures the dollars spent on the modification against the dollars saved in projected life cycle support costs. This information is collected on any modification which suggests such savings, and is mandatory for all proposed modifications based on logistics deficiencies (36). The second payback considers both cost savings and increases in or restorations of capability. This factor consists of a ratio of benefits to costs. While the cost of the modification is relatively easy to determine, the dollar value of the benefits received from the modification are less so. While the precise way to measure this was not studied here, the benefits would include the savings in parts, reduced maintenance hours, reduced downtime, and increased availability. In any case, it appears that this

factor increases the competitiveness of a modification as the ratio increases.

Returning now to figure 2.7, the factors described above all influence the competitiveness of a modification or modifications, which in turn increases the aircraft modifications as a percent of the POM. The Congressional support factor also influences aircraft modifications as a percent of the BES. As the factor increases, so the percent of modifications in the BES increases. The percent of modifications in the BES also increases as the percent of modifications in the POM increases. At the time of the BES, no new programs are proposed (usually), so no other sources of modifications exist. At that time the OSD Comptroller (OSD/AC) first reviews the proposed programs for modifications and will reduce or eliminate modifications, if they appear to fail the criteria for executability, or if in the Comptroller's judgement, the requirement is not justified (45). This review is captured in the OSD/AC mod executability/requirements factor. As the factor increases, so does the percent of the BES devoted to aircraft modifications. Although the relationship is direct, reality suggests that the review tends to decrease the mods. Thus, the percent of the BES applied to aircraft modifications decreases as the OSD/AC Mod executability/requirements factor decreases.

Logically, aircraft modifications as a percent of the BES also influence aircraft modifications as a percent of the President's Budget Request. As the former increases, the latter increases. The DOD financial constraint again comes into play here, with greater influence than previously. At this stage, the Office of Management and Budget (OMB) works closely with DOD to meet the financial constraint which was drafted early in the cycle and is now settled into final form. As this financial constraint factor increases (as the constraint tightens), the percent of the budget applied to modifications seems to increase. As discussed earlier, this increase has been observed as constraints tighten, but the causal relationship has not been verified.

The Congressional support factor, as it increases, also increases the percent of the President's Budget Request devoted to modifications. By this stage of the budget cycle, Congressional action on the previous budget, by law should be complete. The Appropriations Bill should have been passed and in effect. In some years, however, this bill has not been passed prior to the President's presentation of the Budget Request in his State of the Union address. Nonetheless, the effect of Congressional action regarding the previous budget acts on the current budget to a greater degree than it did earlier in the cycle. The

percent of the President's Budget devoted to aircraft modifications is the output of the DOD financial subsector.

External Financial Subsector. After work explained in the DOD financial subsector has been completed. The Office of Management and Budget, the President and Congress use that input to combine the funding requirements of DOD with other government agencies. The result of the work done by the external financial subsector is the federal budget for a given year. This subsector examines the budget enactment process conducted by Congress to extract its influences on the aircraft modification budget. The discussion of this subsector follows.

The external financial subsector begins with aircraft modifications as a percent of the President's Budget pictured in the top left hand corner of figure 2.9. Aircraft modifications as a percent of the President's budget request, along with the total size of the President's budget, influence Congressional pressure to reduce the DOD budget. As the former increases, it appears that the pressure to reduce the DOD budget decreases. An increase in the total size of the President's budget, on the other hand, tends to increase Congressional pressure to reduce the DOD budget. In eventually measuring this effect, it may be best to measure the difference between the President's DOD budget as presented and as expected by the Congress, rather than simply the size of the total budget,

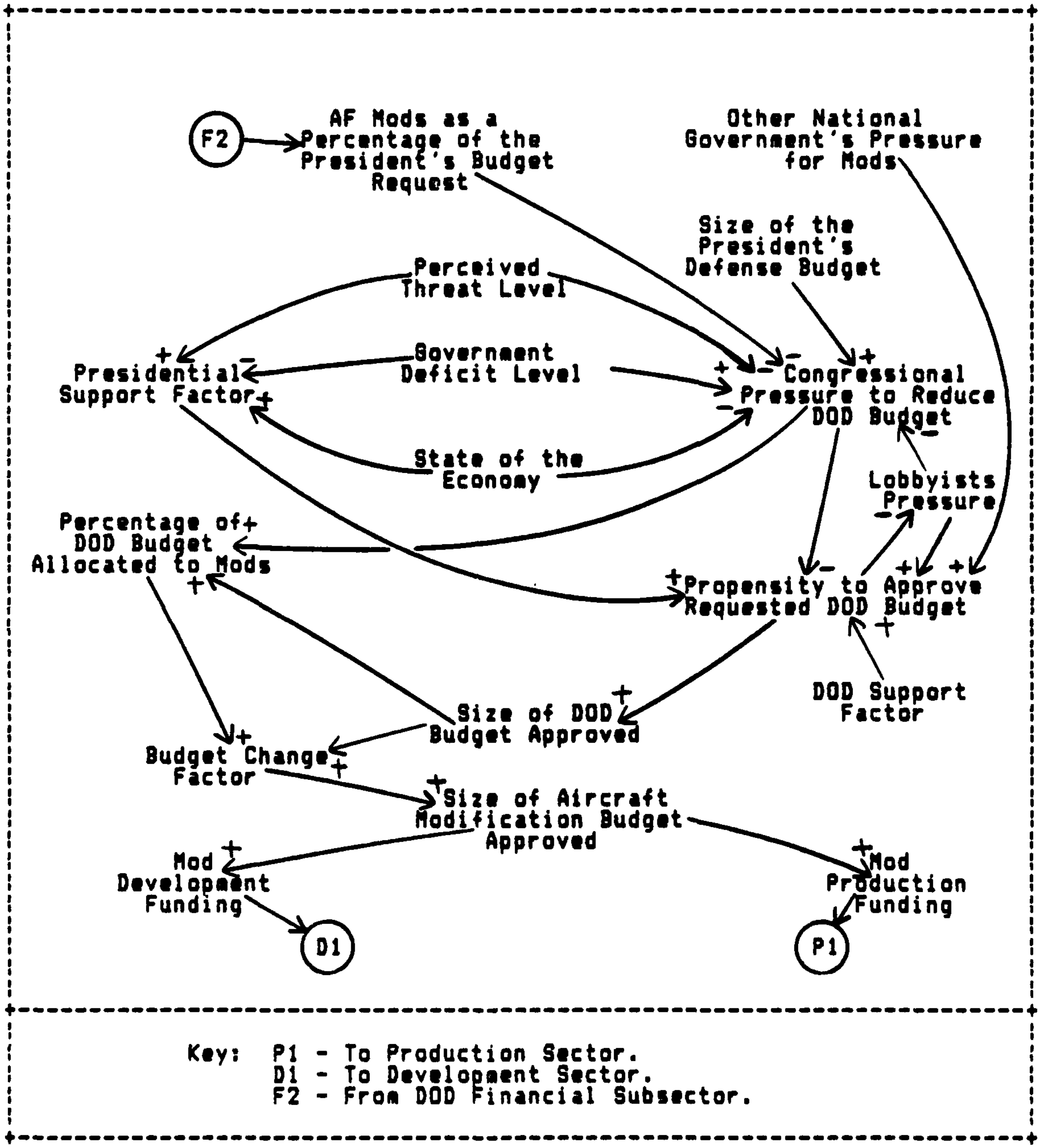


Fig. 2.9 External Financial Subsector (F3)

or the size of the DOD budget. The effect of the DOD budget on Congress is complex. It requires considerable study to properly capture the relationships and the direction and magnitude of these relationships.

Several other variables influence Congressional pressure to reduce the DOD budget. Improvements in the economy, as measured by Gross National Product per capita, tends to decrease pressure to reduce the DOD budget. Similarly, as the level of perceived threat from potential enemies increases, the Congressional pressure to reduce the DOD budget decreases. In recent years, the increasing level of the government deficit has increased Congressional pressure to reduce the DOD budget. An appropriate measure for this is dollars of deficit per capita.

Each of these factors also affects the Presidential support factor regarding the defense budget. As the perceived threat increases, Presidential support increases. As the state of the economy improves, support increases. As the government deficit increases, however, Presidential support decreases.

The Congress, then, has some propensity to approve the requested budget, which is influenced by the pressure to reduce the DOD budget and the Presidential support factor, among others. As the pressure to reduce the DOD budget increases, then the propensity to approve the requested budget decreases. The Presidential support factor

counteracts that pressure. As the support increases, the propensity to approve the requested budget also increases.

Special interest groups and defense contractor lobbyists are a fact of life in Congress today. Their interests and pressure have a real influence on the activities of Congress. In the causal loop diagram, the pressure of the defense contractor lobbyists influences both Congressional pressure to reduce the DOD budget and the propensity to approve the requested budget. As the lobbyists' pressure increases, Congressional pressure to reduce the DOD budget decreases and the propensity to approve the requested budget increases. As the propensity to approve the requested budget increases, it in turn reduces the lobbyists' pressure.

For some programs DOD expresses special support in an attempt to influence the changes being made by Congress. The effectiveness of this support depends on how important the program is to DOD, how well the testifying individual has prepared, and what else is being questioned by the Congress at the time. This support factor does change Congressional actions, however, according to the Armed Services Committee staff members interviewed (30; 44). Thus, the DOD support factor, as it increases, increases the propensity to approve the requested budget.

Some of the programs pursued by DOD are international programs. Other nations plan to buy the equipment being

developed, or change their existing equipment with planned modifications. If the Congress proposes cuts in such programs, phone calls from high-ranking diplomats have caused such proposed actions to change (49). Thus as the other national governments' pressure for modifications increases, the propensity to approve the requested budget increases.

As the propensity to approve the requested budget increases, the actual size of the DOD budget approved increases. As it increases, the percent of the DOD budget allocated to modifications increases. The latter level is also increased by an increase in Congressional pressure to reduce the DOD budget. As the size of the DOD budget increases, and as the percent of the DOD budget allocated to modifications increases, the budget change factor increases. This is a factor created to convert the percent of the DOD budget allocated to modifications and the size of the DOD budget into the size of the aircraft modification budget approved. Basically, it multiplies the first two variables to get the third.

The aircraft modifications budget approved is divided into the modification development funding level and the modification production funding level. Both of these increase as the aircraft modifications budget approved increases. The development funds and the production funds are inputs to the development and productions sector,

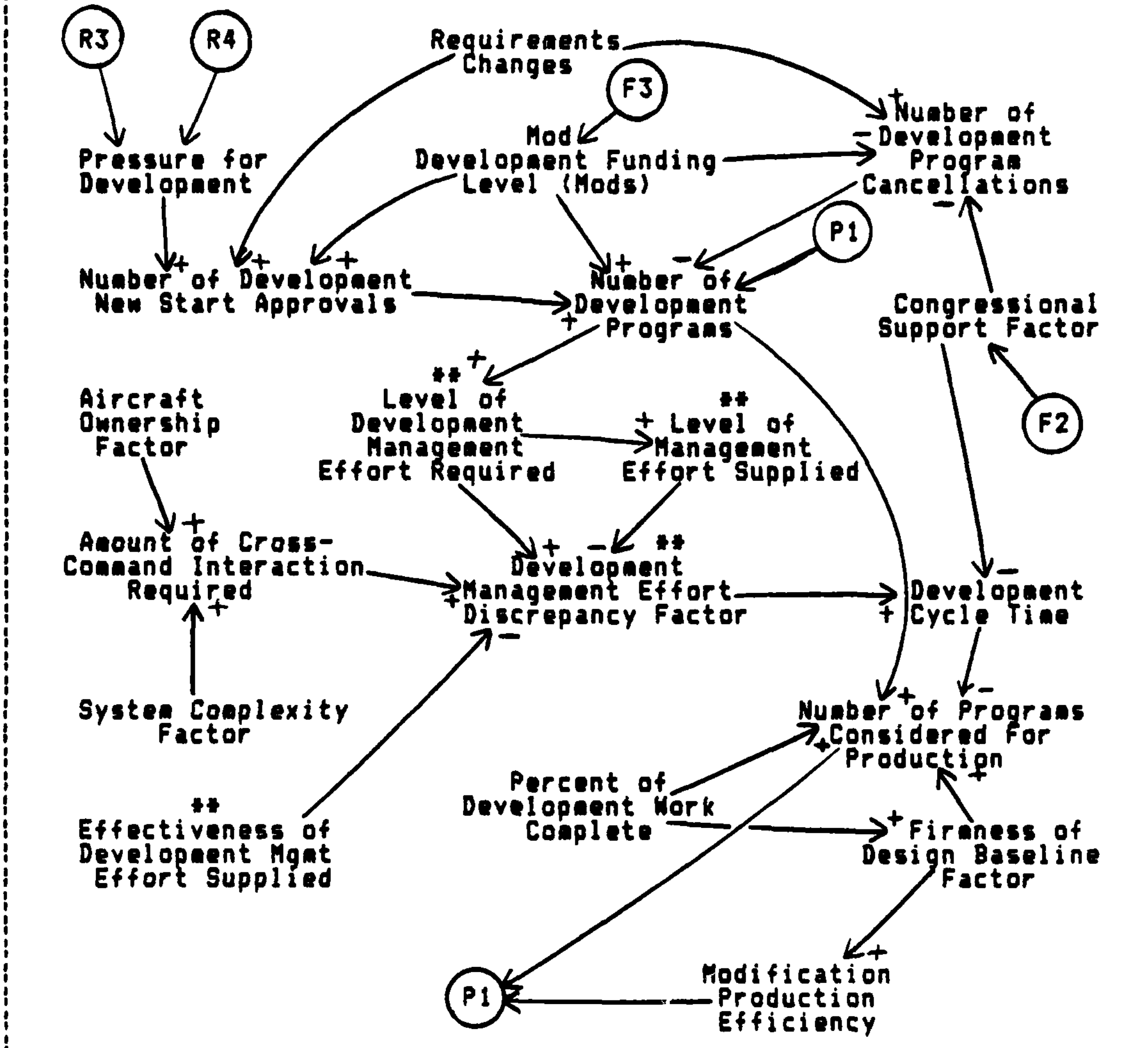
respectively. This completes discussion of the financial sector. The development and production sectors are discussed next.

Development Sector Part 1

Shown in the development sector is the effort necessary to transition modifications from the conceptual or laboratory phase to the production phase of the process. Figure 2.10 shows the causal relationships that form this portion of the conceptual model of the aircraft modification process. Discussion of these relationships appears in the following paragraphs.

The development sector begins with pressure for development, which comes from the requirements sectors, and with the level of development funding for modifications, which comes from the external financial subsector. Any modification requirement which survives the requirements approval process results in increased pressure for development (if the modification requires development), which in turn increases the number of development new starts approved.

The approval of a new development program follows a different process than the requirements approval process or the funding approval process. This process, for major programs, is regulated by OMB Circular A-109 (38) and the resulting DOD directives and instructions. Less than major programs are considered with the same system, but at a lower level of management, and are provided with more



Key: R3 - From the Class IV Requirements Approval Subsector.
R4 - From the Class V Requirements Approval Subsector.
F2 - From the DOD Financial Subsector.
F3 - From the External Financial Subsector.
P1 - To the Production Sector.
** - Detailed in the following Development Management Subsector.

Fig. 2.10. Development Sector (D1)

flexibility. The major system acquisition process, which has been studied at length, is at least, or more involved than the modification process (50). Therefore, the acquisition process will not be explored in depth here. Suffice to say that the output of that process is the number of development new start approvals.

Also influencing the number of development new starts is the level of development funding for modifications. As the level of funding increases, the number of development new start approvals increases. Similarly, as the level of development funding available for modifications increases, and as the number of development new starts increase, the number of development programs for modifications increases.

Counteracting these increases in numbers of programs is the number of development program cancellations. Programs are cancelled for a variety of reasons, such as changing requirements, technical difficulties, and elimination of funding by the Congress. For the purposes of this study, the reasons for cancellations will be a reduction in development funds, or a reduction in the Congressional support factor (described in the DOD financial subsector), or changes in requirements. In reality, very few programs are cancelled. Most are continued, but on a longer schedule, or at a very reduced level until funding is restored. In any case, as the level of development funding for modifications increases (decreases), the number of program

cancellations decrease (increase). As Congressional support increases (decreases), the number of program cancellations decrease (increase). As requirements changes increase, the number of program cancellations increase. Such changes may result in additional new starts as the cancelled program is replaced with one that satisfies the new or changed requirement. Then, as the number of program cancellations increases, the number of active development programs decreases.

As the number of modification development programs increase, the level of development management effort required increases. The management described here may occur in AFSC or in AFLC, and the funding may be research and development money, or sustaining engineering money. Most of the funds will be research and development, and most of that work will be done by AFSC. Conversely, most of the work associated with sustaining engineering development will be done by AFLC.

The simplest management task is found in the situation where the aircraft to be modified is under the control of the same command that will do development and implementation of the modification on the aircraft. If that command is AFLC, the task is simplest of all. Little or no interaction between the two commands is required. If AFLC owns the aircraft, but AFSC will develop the modification for that aircraft, then the management task is most

complex. In this case, there must be substantial interaction between the commands early in the development process and continuing at a high level throughout the development cycle and into production. The required interaction involves designing for support and establishing support requirements in the early design stages of the mod. It also includes coordinating what the aircraft's baseline will be at the time of projected installation, and projecting the schedule of mod installations to coincide with planned depot maintenance and ongoing modifications on the aircraft. They must plan and budget for new skills training and equipment for the maintenance people, and set changeover schedules for using bases to convert from supporting and using the unmodified aircraft to the modified version. This is further complicated by increasing the complexity of the system to be modified and the complexity of the modification itself.

Experience shows, and interviewees' remarks confirm, that such interaction is difficult to achieve, manpower-intensive, and subject to numerous conditions and contingencies. To capture these subtleties, a discrepancy factor was used. This discrepancy factor, and the other elements of management, are expanded in the development management subsector, which follows below. After the expansion of this factor, focus will return to the second part of the development sector.

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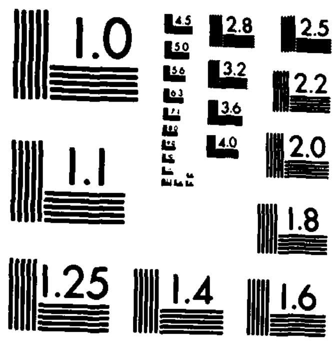
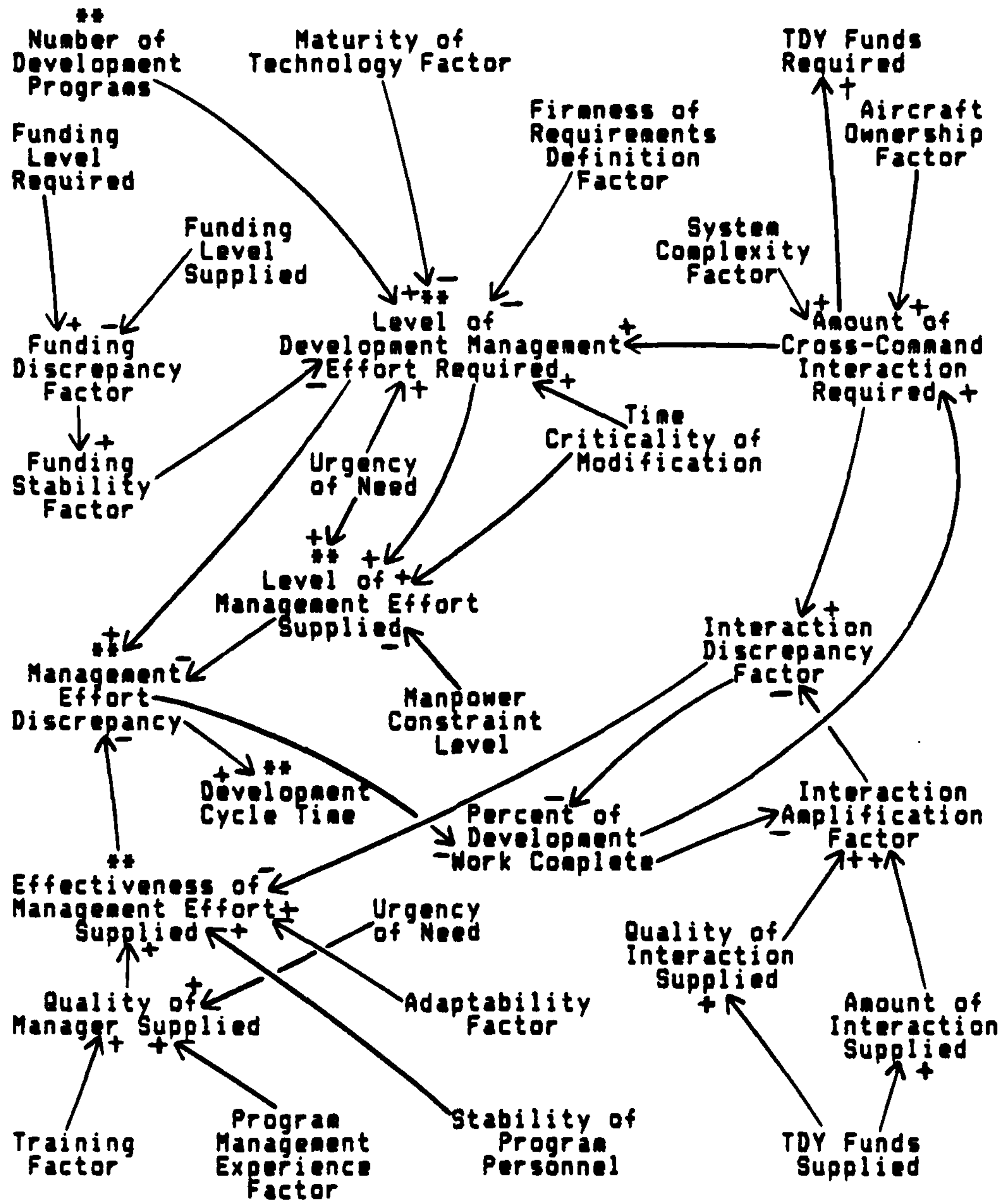


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Development Management Subsector. As can be seen in the development management subsector (figure 2.11), there is an interaction discrepancy factor, which is created by a combination of the amount of cross-command interaction required and the amount of interaction supplied, as amplified through the interaction amplification factor. The discrepancy factor is increased by an increase in the amount of cross-command interaction required. The amount of cross-command interaction required is increased by an increase in the system complexity factor, and by an increase in the aircraft ownership factor. The discrepancy factor is decreased by increases in the interaction amplification factor. This latter factor collects the effects of the amount of interaction supplied, the quality of that interaction, and the element of time (as represented by the percent of development work complete). As the amount and quality of interaction increase, the interaction amplification factor increases. As the percent of development work complete increases, however, the interaction amplification factor decreases. A high factor, therefore, decreases the interaction discrepancy factor which, in turn, tends to improve the effectiveness of the development management effort supplied.

The purpose of this particular discussion is to isolate a very important element of modification management. In all development work it is important for interaction



Key: ** - Variables Shown in the Development Sector.

Fig. 2.11. Development Management Subsector (D2)

between AFSC and AFLC people to begin early enough for support considerations to affect the design. The resulting aircraft will eventually comprise part of the United States' weapon system capability. In modification management this is especially important because the planned changes will affect operational aircraft, and thus affect current war-fighting capability. It has also been demonstrated (41) that this interaction must begin at the very earliest possible stage of development, even before design begins, to result in a supportable system that delivers the promised capability. Therefore, the percent of development work completed at the time interaction begins provides some insight into how well the interaction supplied will accomplish its purpose. Additionally, the amount of interaction required will increase as the percent of development work complete increases. Thus, if the percent of development work complete is high, then the interaction supplied, even if of very high quality, will be less than required. Following from this, as the interaction discrepancy factor increases, the percent of development work complete decreases. This indicates that the amount of work to be done actually increases as cross-command interaction finally begins, mistakes are discovered and corrected. Some interviewees (34; 36; 51) believe that AFLC is discovering and correcting design errors and logistics support errors, among others, from the time the system is

transferred to it until it is retired from service. In other words, if interaction does not begin before design begins, the interaction discrepancy never can be resolved. It may be a challenge to find any weapon system that does not fall into this situation.

Germane to the discussion of cross-command interaction is the subject of travel or temporary duty (TDY) funds. As the amount of cross-command interaction required increases, the level of travel funds required also increases. Only so much interaction can be done on the telephone, one to one. Many issues of supportability are at odds with operational capability requirements, or with cost or schedule requirements. These issues can best be worked out at meetings to which some people must travel. As the required interaction increases, the level of TDY funds required also increases. If these funds are not provided, then the amount and quality of interaction supplied is degraded. With travel funding receiving increasing criticism, and the predictable cuts, this seemingly insignificant variable can become a determining factor in the effectiveness of modification development management and interaction between AFLC and AFSC.

The discussion of interaction began as one of the factors that influences the amount or level of development management effort required. As the amount of cross-command interaction required increases, the level of development

management effort required increases. Several other factors influence this variable. The maturity of the technology being employed in the modification is significant. When new technology is being converted from research to application, difficulties arise as the solutions that worked when implemented by scientists and engineers are found to be impossible, impractical, or unreliable in a typical factory environment. More mature technology has already passed that stage, and its implementation into new applications is significantly less troublesome. Thus as the maturity of technology factor increases, the level of development management required decreases.

Another factor affecting development management required is the firmness of the requirements definition on which the modification is based. If the using command cannot decide on the requirement, or if the definition of the requirement is nebulous, or if the requirement changes during the course of the development effort, then there will be considerably more management attention directed to changing the modification design in reaction to requirement changes. Thus, as the firmness of requirements definition factor increases, the level of development management effort required decreases.

Stability of funding for programs has received considerable attention in the studies of acquisition management. The conclusion universally has been that funding must be

stable. If it is not, the management of the program becomes more difficult as the program manager rearranges and reduces or increases the work of the program in attempts to fit the new and changing funding profile. This aspect of the system is captured in a funding stability factor, which is affected by a funding discrepancy factor. This discrepancy factor is created by the combining of the funding level required and the funding level supplied. As the funds required increase (decrease), the discrepancy factor decreases (increase). As the funds supplied increases (decreases), the discrepancy factor increases (decreases). While discrepancies in both directions cause more work, the situation in which the supplied funds are greater than the required funds is much less disturbing than when the required funds are greater than the supplied funds. As the discrepancy factor increases, the funding stability factor decreases. As the funding stability factor increases, the level of development management effort required decreases.

Two final factors that influence the level of development management effort required are the urgency of need for both the system and the modification and the time criticality of the modification. The urgency of need is a factor described in the discussion on the DOD financial subsector. As the urgency of need factor increases, the level of development management effort required also increases. The time criticality of the modification is a

factor which considers how the schedule for development of the modification is being driven. If the development work is allowed to take the "normal" amount of time, this factor has no effect on the management effort. If the schedule is compressed, however, the factor increases, and as it increases, the level of development management effort required increases. With these two factors in the system, the buildup of the level of development management effort required is complete.

As the development management level of required effort increases, it tends to increase the level of development effort supplied. At first, the effort supplied will come from existing resources via longer hours for people, or more constant utilization of equipment through sharing, etc. Eventually, however, the existing resources are exhausted, and additional resources must be annexed. A basic tenet of acquiring resources, whether funds, manpower, or equipment, is that the requirement submitted to higher authorities must exceed current resources by enough to outweigh other submittals. Eventually an increase in required development management effort will increase the management resources available, and thus the management effort supplied. The manpower constraint level has a restraining effect on increases in management effort supplied. As the constraint tightens (increases), the level of development management effort supplied decreases.

Rarely does the effort required match the effort supplied. Thus, there is a management effort discrepancy factor.

The management effort discrepancy factor increases as the development management effort required increases and decreases as the development management effort supplied increases. The factor also decreases as the effectiveness of the development management effort supplied increases. The discrepancy factor, in turn, increases development cycle time as it increases. With this action, the factor recognizes that insufficient management effort results in ineffective control. As the interaction discrepancy factor increases, the percent of development work complete actually decreases, which indicates the presence of mistakes and rework or of additional, unforeseen tasks. The increase in development cycle time reflects the schedule stretchout that results from insufficient or ineffective management.

The effectiveness of development management effort supplied is a level derived from several factors and levels. As the interaction discrepancy factor, which was developed earlier, increases, effectiveness decreases. Effectiveness of management is also influenced by the quality of the managers supplied, the stability of program personnel, and the personality of the manager. The quality of the managers is determined by the amount and type of training and the amount and type of experience. Training and

experience are expressed as factors. The quality of managers supplied also is affected by the urgency of need for the modification and the system. Higher visibility programs tend to get the best qualified people, the most stable funding, and the most help when required (49; 51). Thus as the urgency of need, training and experience factors increase, the quality of the managers supplied increases. As the quality of the manager supplied increases, the effectiveness of the development management effort supplied increases.

The stability of program personnel is important to the success of a development effort. Much has been written about the importance of keeping program directors (or managers) in the job long enough to learn it and achieve some level of effectiveness. One very experienced interviewee, however, felt that the stability of the the key managers at lower levels (the program personnel like engineers, project managers, procurement officers, logistics people) was much more germane (34). Guarino, Lilly, and Lindenfelser, in their article "Faith Restored - The F-15 Program" agreed (28:44). In addition to stability, the importance of the personality of the manager to his or her effectiveness was identified by many of the interviewees (8; 9; 23; 29; 33; 34; 35; 36; 37; 48; 49; 51). An adaptability factor is used to express that influence. The personality factor and the measurement of

its elements, however, would require another seperate research effort. Regardless of the way it is eventually measured, an increase in the adaptability factor increases the effectiveness of the development management effort supplied, as does an increase in the stability of program personnel. An increase in the effectiveness of the development management effort supplied decreases the development management effort descrepancy factor.

This completes the development management subsector. The development cycle time variable ends this subsector and returns the discussion to the development sector and figure 2.10.

Development Sector Part 2

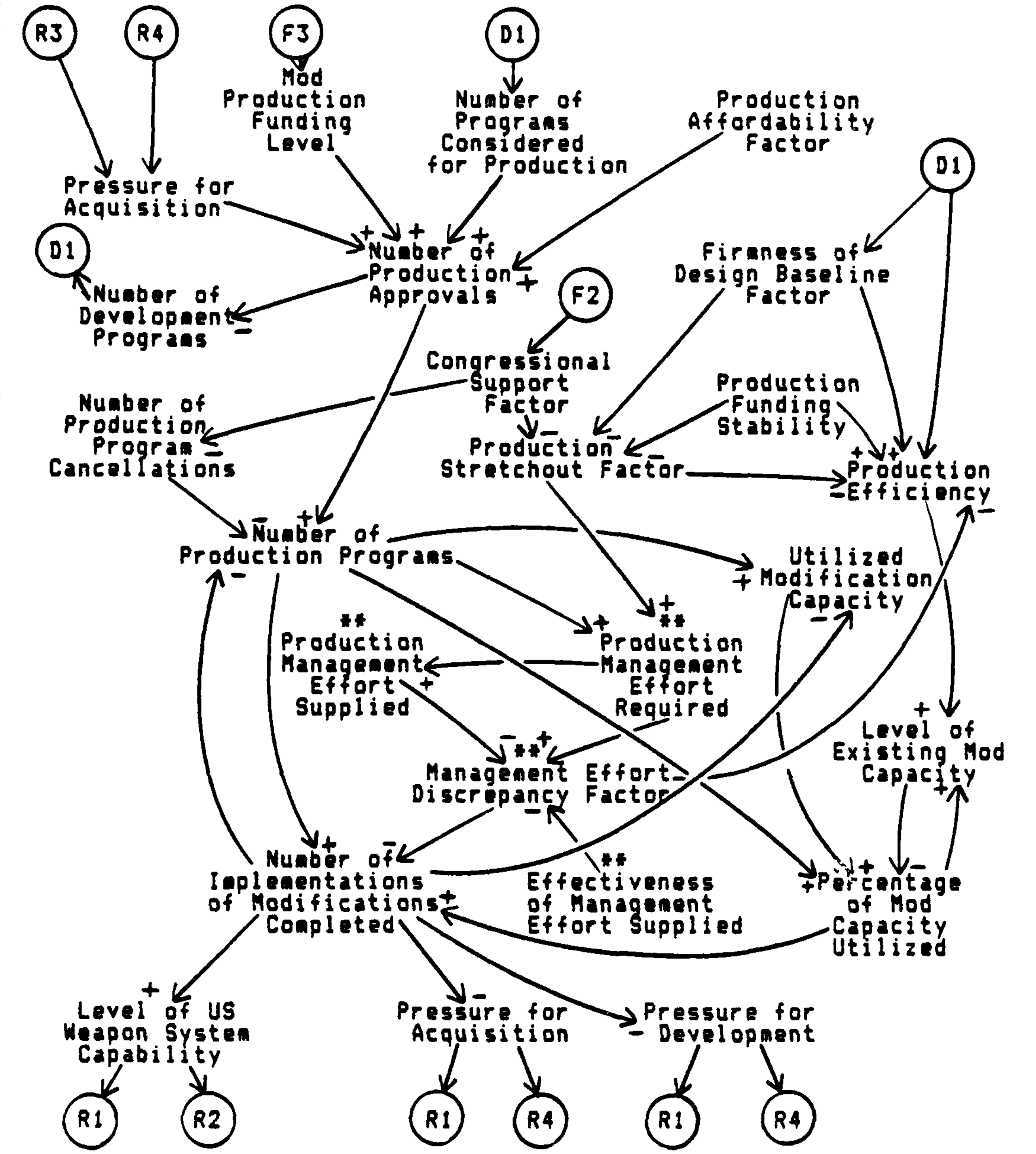
As the development management effort discrepancy factor increases, it causes the development cycle time to increase. At any point in time there are some number of programs being considered for production (including implementation). As the development cycle time increases, the number of programs considered for production decreases. This number increases, however, as the percent of development work complete increases. As the percent of development work complete increases, hopefully the firmness of the design baseline also increases. This is not always the case, however. Numerous programs, such as the Joint Tactical Information Distribution System (JTIDS) program, pursue production concurrent with completion of development

work. The implication of this is that the production design baseline changes during the production of end items. A changing baseline means production items that are not all alike, thus rendering impossible the requirement to kit-proof a production kit before beginning regular kit installations. Logically, the efficiency of the production of kits, the installation and checkout of the modification, and the subsequent support of the modified aircraft is compromised by this situation. Therefore, as the firmness of the design baseline factor increases (decreases), the modification production efficiency increases (decreases). The modification production efficiency, the firmness of the design baseline factor, and the number of programs considered are inputs to the production sector.

Production Sector Part 1

The production sector has the most involvement with other sectors. The requirements, finance, and development sectors all provide inputs. The structure, as shown in figures 2.12 and 2.13, is similar to the development sector. In fact, many of the variables differ only in the phase name (production management, rather than development management).

Much like the development sector, the number of program approvals--in this case production programs--is a primary variable. The number of production approvals is increased by an increase in the pressure for acquisition, which



Key:
R1 - To/from Class IV Requirements/Capability Subsector.
R2 - To Class V Requirements/Capability Subsector.
R3 - From the Class IV Requirements Approval Subsector.
R4 - To/from the Class V Requirements Approval Subsector.
F3 - From the External Financial Subsector.
D1 - To/from the Development Sector.
** - Detailed in the Production Management Subsector.

Fig. 2.12. Production Sector (P1)

originates in the requirements sectors. From the development sector, an increase in the number of programs considered for production tends to increase the number of production approvals. And from the financial sector, an increase in the production funding level tends to increase the number of production approvals. Also considered in the production approval decision is an affordability factor, which, as it increases, increases the number of production approvals. Essentially, then, the production approval process depends on four elements: the number of development programs ready for consideration for production, the pressure from the requirements sector for the addition of capability or correction of deficiencies through direct production programs, the funds available for modification production (including installation), and some measure of the affordability of the modification(s).

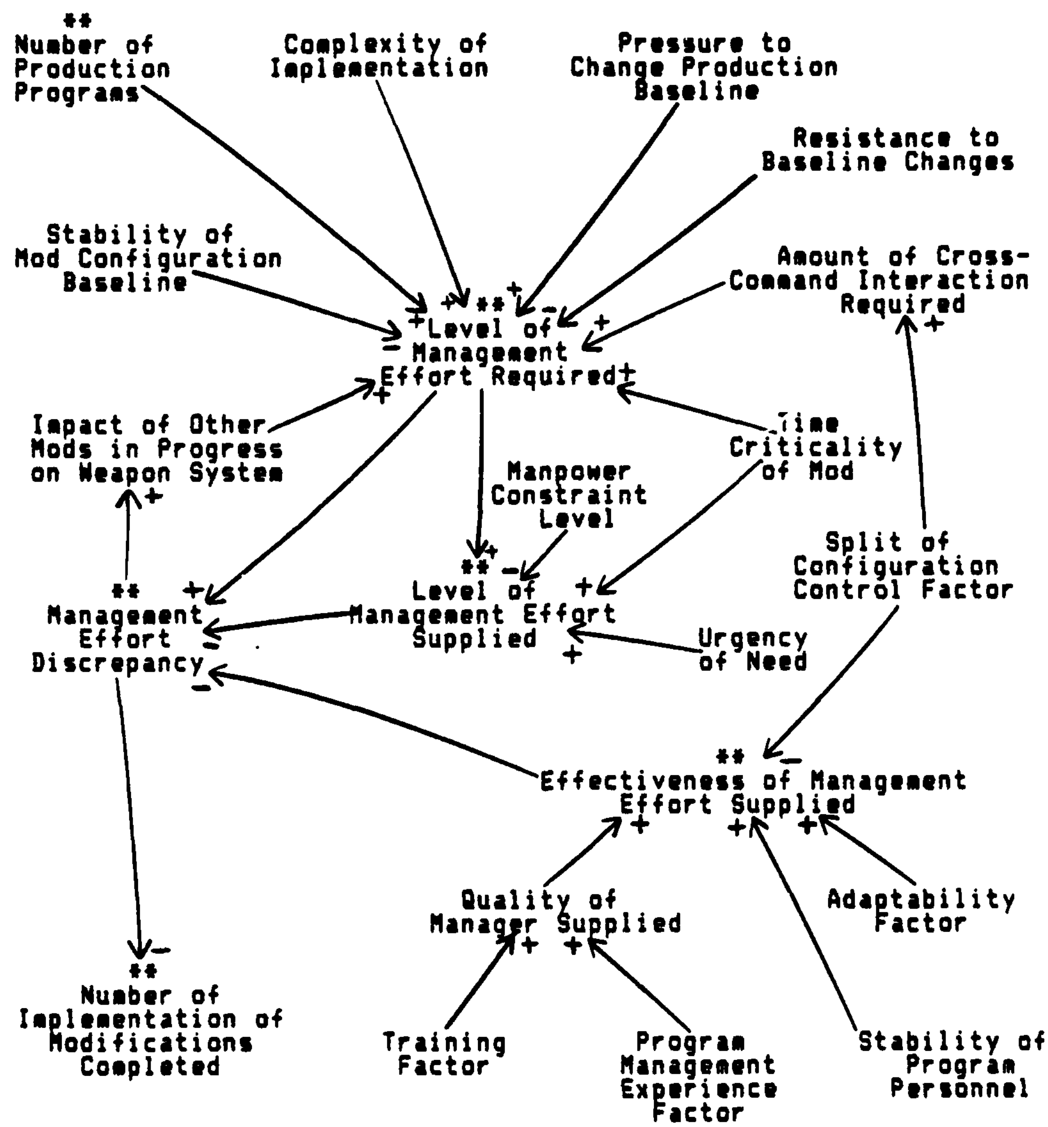
Once the production approvals increase, the number of production programs increase and the number of development programs decrease. Production programs are reduced, however, by an increase in the number of production cancellations. When the number of production programs increase, the level of production management effort required and, eventually, the level of modification capacity increases. The level of production management effort required is very similar to the development management effort required. There are variables for the level of

production management effort supplied, effectiveness of production management effort supplied, and production management effort discrepancy. These variables also stand in the same basic relationship to one another in the production sector as they do in the development sector. That is, as the level of production management effort required increases, the level of production management effort supplied and the management effort discrepancy both increase. But, as the effort supplied increases, it tends to decrease the management effort discrepancy. Similarly, as the effectiveness of production management effort supplied increases, the management effort discrepancy decreases. The differences from the development sector are found in the variables that influence these primary variables.

In the production sector itself, the level of production management effort required is influenced by a production stretchout factor. This factor collects the effects of the firmness of the design baseline, the production funding stability, and Congressional support on the scheduling of the production and implementation of the modification. The tendency, when faced with difficulties in any of these areas, is to stretch out the production in order to keep the trained teams and the specialized equipment together for the time when the difficulty is resolved. Hence, when the design problems are settled, or when the funds are restored to the required profile, or

when the attention of the Congress turns elsewhere, work can be resumed. Thus, as the firmness of the design baseline increases, the production stretchout factor decreases. When the production funding stability increases, the stretchout factor decreases. And, when the Congressional support factor increases, the production stretchout factor decreases. For the influencing factors the expectation is that one or more would be decreasing, thus increasing stretchout of the production program. As the production stretchout factor increases, the level of production management effort required increases.

Production Management Subsector. The production management subsector (figure 2.13) and the development management subsector are substantially different. In the production environment, the operational aircraft is drawn out of operations into the depot or contractor's plant for implementation of the modification. Conflicting requirements arise as the user wants all aircraft modified as fast as possible and simultaneously wants the fewest possible aircraft drawn down for modification. Other modifications are probably being implemented at the same time, which creates a configuration baseline control problem and likely a scheduling problem as well. Some modifications are very complex in implementation, which adds to the management burden. In any modification, especially one coming from development, there is pressure to change the configuration



Key: ** - Variables shown in the Production Sector.

Fig. 2.13. Production Management Subsector (P2)

baseline of the modification kit; balancing that is resistance to change, which varies by manager and by policy. Aside from active pressure to change the modification kit there may be residual tasks from development which result in an unstable baseline. And, there may be the complicating factor of cross-command interaction, which, like in the development management sector, increases the required level of management effort required. To reflect these influences there are factors for the complexity of implementation, pressure to change, impact of other modifications in progress on the weapon system, amount of cross-command interaction required, and time criticality of the modification. Each of these variables causes an increase in the level of production management effort required as it increases. There are also factors for resistance to change and stability of the modification configuration baseline; as these increase, the level of production management effort required decreases.

As the level of production management effort required increases, the effort supplied also increases. The increase in production management effort supplied is moderated by the same manpower constraints encountered in the development management subsector, and is increased by the time criticality of the modification factor and the urgency of need/weapon system priority factor, also both encountered previously.

As the level of production management effort required increases, as mentioned earlier, it tends to increase the production management effort discrepancy factor. An increase in the level of production management effort supplied decreases the production management effort discrepancy factor. The discrepancy factor is also decreased by an increase in the effectiveness of the production management effort supplied. In turn, an increase in the production management effort discrepancy factor increases the impact of other modifications in progress on the weapon system, and decreases the number of implementations of modifications that can be done.

The effectiveness of production management effort supplied closely resembles the effectiveness of development management effort found in the development management subsector. The impact of training and experience on quality, and the stability of program personnel, and the adaptability factors all act on the effectiveness of the management just as they did in the development management subsector. A new variable is the split of configuration control factor. As mentioned previously, the most difficult management task occurs when the aircraft is owned by one command, usually AFLC, and the modification is being designed and possibly implemented by AFSC. The worst possible scenario occurs when the configuration control of the aircraft is split between the two commands. In this

situation no one really has control of the aircraft configuration; the result can be chaotic. An example of the result of this is the F-4: no one really can determine the exact configuration of certain aircraft which had been caught in a split configuration management environment. In fact, a former maintenance officer said that he had at one point 75 F-4s to maintain in 23 different configurations (10). To successfully manage a split configuration control situation requires a great increase in the amount of cross-command interaction required, and tremendous management effectiveness. The effect in the diagram of an increase in the split of configuration control factor is to increase the amount of cross-command interaction required, just as mentioned, and to decrease the effectiveness of production management effort supplied.

Production Sector Part 2

Returning now to the production sector (figure 2.12), it was said earlier that an increase in the management effort discrepancy decreased the number of implementations of modifications completed. This implies that if the management effort discrepancy decreases, then both the number of aircraft modified by one modification kit type increases and the number of modification types implemented increases. In addition, as the number of production programs increase, the number of implementations of modifications completed increase.

The ability to support this increase is constrained by the capacity of the support system to perform modifications. If the number of production programs increase, then the utilized modification capacity, and the percent of capacity utilized, both increase. If the percent of the modification capacity increases, that places pressure on the level of existing modification capacity to increase. As the modification capacity increases, then the percentage of the capacity being used decreases. As that percentage used increases, the number of implementations of modifications being completed also increases.

The modification capacity is also increased by an increase in production (including implementation) efficiency. Production efficiency is improved by increases in the firmness of the design baseline and in the production funding stability, and decreased by increases in the production stretchout factor. According to an interviewee, funding is rarely a problem for production after the first two years when kitproofing is done (34). Thus the impact of funding instability depends on timing. Production efficiency is decreased by an increase in the management effort discrepancy factor.

When the number of implementations of modifications increases, there is a corresponding increase in the level of U.S. weapon system capability. In other words, when modifications are incorporated into the aircraft the new,

The ability to support this increase is constrained by the capacity of the support system to perform modifications. If the number of production programs increase, then the utilized modification capacity, and the percent of capacity utilized, both increase. If the percent of the modification capacity increases, that places pressure on the level of existing modification capacity to increase. As the modification capacity increases, then the percentage of the capacity being used decreases. As that percentage used increases, the number of implementations of modifications being completed also increases.

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When the number of implementations of modifications increases, there is a corresponding increase in the level of U.S. weapon system capability. In other words, when modifications are incorporated into the aircraft the new,

improved, safer, or newly available capability materially increases the capability of U.S. defense forces. This also decreases the number of production programs, and the level of outstanding requirements, in the form of pressure for development and acquisition. This closes the loop and returns action to the requirements sector to begin again.

Summary

This completes the discussion of the conceptual model of the USAF aircraft modification process and its structural relationships. In Chapter III, a discussion of model validation is presented. Following this, the key issues of the modification process are presented in the problem analysis.

III. Model Validation and Problem Analysis

Introduction

In chapter II, the conceptual model of the Air Force aircraft modification process was presented and discussed. Next arises the question of the validity of the model, and given validity, the implications of the relationships structured in the model. The first section of this chapter contains a discussion of the validation of the model. In the second section are presented the key issues of the aircraft modification process. The potential problem areas within the process are analyzed and implications discussed in this section.

Model Validation

Introduction. Validation of any model is required to demonstrate that confidence may be placed in the analyses performed with the aid of the model. Richardson and Pugh state a basic premise of validity as "it is meaningless to try to judge validity in the absence of a clear view of model purpose." (42:310) With this in mind, recall from Chapter I that the purpose of the model is to capture the significant aspects of the aircraft modification process and present them in a form that can be used to amplify the experience and judgement of the decision-maker when critical decisions are being made. The specific goal of this effort is a model that is understandable to the decision-

maker, that truly represents the structure of the system, and that supports the decision-maker's assessment of potential policy changes.

With the purpose and goals restated, the next step is to examine the validation process itself. But, as Richardson and Pugh relate, "in the system dynamics approach validation is an on-going mix of activities embedded throughout the iterative model-building process [42:311]." Shannon also states that validation is "the process of bringing to an acceptable level the user's confidence that any inference about a system derived from the simulation [model] is correct [41:29]."

Validation of a conceptual model of a system must, therefore, involve integration of the model builder's experience and knowledge with the information gathered from managers overseeing the operation of the system and from other published information. Validation of the model is not carried out in isolation from the actual modification process, but with the cooperation of decision-makers and policy-makers directly concerned with the system processes. Throughout its development, a model and its internal relationships must be tested and validated.

Specific tests or techniques for validating conceptual models are not described in the literature. A general test developed by A.M. Turing, however, can be extended to apply to a conceptual model. Shannon describes the need for a

test that can increase confidence in models that operate under nonstationary or non-steady state conditions. He identifies the Turing test as the only one which can apply to these models, and describes it as follows.

> Turing was actually trying to provide a way for comparing human and machine intelligence when he suggested the procedure. The test hinges on the notion of an imitation game. To run it, we find a person or persons who are intimately familiar with the operations of the system being studied. We then present them with one or more sets of input-output data from the real world system and one or more data sets from the model and ask them to differentiate between them. If they succeed, we ask how they were able to do it. This then gives us a clue as to what might be wrong [or right] with our model [43:228].

The aircraft modification process model is not operational in the sense of a computer model, but it does deal with situations where non-steady state conditions are the norm. This suggests that the Turing test could be used. Application of the Turing test to the aircraft modification process model requires two extensions to the basic design of the test. First, the causal loop diagrams of the conceptual model become the "data sets" output from the model. Second, the experience of managers in the modification process and their understanding of the structure and relationships of the process takes over in the Turing test as the "data from the real world." Using these two extensions, the Turing test can be applied to a system dynamics conceptual model. The Turing test combined with the system dynamics approach [where validation is "an ongoing mix of activities embedded throughout" (41:311)] is the approach

taken to validation of the conceptual model. The actual application of this combination to the aircraft modification process model is documented in the following section.

Testing the Model. The testing of the aircraft modification process conceptual model began with the creation of causal relationships between variables during the initial development of the model. The decision-makers involved in the actual modification process were interviewed (see Interview Guide 1 in Appendix D) in order to collect information about the process prior to any development of the conceptual model. The development of the model employed that information to set up relationships between variables in the modification process. As the Turing test dictates, each relationship between variables was carefully and repetitively checked against the actual modification process. Access to experts in the aircraft modification process before and during the development phase of the conceptual model helped to eliminate poor or incorrect constructions in the model structures.

After the initial structure was developed, the second set of interviews (see Interview Guide 2 in Appendix D) with decision-makers were conducted to fully test the model. Each interviewee first was given a short introduction to the technique of causal loop analysis. Once an understanding of the causal loop diagrams was established,

the variables used in each diagram were explained. Then each interviewee scrutinized the diagram to locate flaws in the structure depicted. As flaws were identified, the interviewee was prompted to describe the difference between the actual process and the model. With this information, the flaw was corrected. This continued for all the diagrams, and all the interviewees. Where extensive flaws were found, past interviewees were revisited to ensure that revisions captured the proper structure and behavior of the modification process. As the round of interviews progressed, the flaws found became fewer, and the degree of confidence in the model increased. The increasing validity of the model was apparent from the remarks of the decision-makers interviewed late in the second trip to Washington. Some felt that they had gained more insight into the aircraft modification process from the diagrams and the discussion than they had been able to contribute. The conceptual model presented in Chapter II is the final product of the development and validation process described above. After validating the model, the next step is analysis of the key issues highlighted by the model.

Problem Analysis

Part of the purpose of modeling the aircraft modification process is to capture the significant aspects of the process. "Significant aspects" means those elements of the process, or the model, that cause it to behave as it does.

Within those significant aspects of the model are found the issues of the actual process being modeled. During the process of gathering information from literature and from the experts and decision-makers interviewed, a number of issues were either mentioned or became apparent. As the conceptual model of the aircraft modification process developed and went through validation, the issues became better defined. After considerable discussion and revision, five key issue areas were identified that drive the behavior of the model and of the aircraft modification process. In this section, the five key issue areas are discussed.

The key issues of the process are the management approach to modification of aircraft, the way that Class IV requirements are approved, the management complexity associated with split management, the ranking of modifications by funds allocation, and the personality dependence of the entire modification process. There is some overlap from issue to issue, but these divisions best delineate the major behavior drivers in the process. Each issue area will be discussed in an individual section below, in order of significance.

Systems Approach to Management. Air Force weapons, missiles and aircraft are commonly called systems--weapon systems is the usual term. Cleland and King describe a system as a "conglomerate of interrelated and interdependent

parts [12:142]," parts which must interact in order for a system to perform its mission. The systems approach to management recognizes this requirement for interaction of parts and the management of a system is structured in accordance with that viewpoint.

The greatest utility from the systems viewpoint is found in a dynamic context, where the systems "are evolving over time" (12:149). The potential for application of the systems approach to the modification of the Air Force's complex aircraft is clear. With the numerous modifications ongoing, in development, in production, funded but not started, approved but not funded, and in planning for every aircraft in the inventory, some organized approach to management is required. It appears that the systems managers responsible for the aircraft use an organized approach to management, but it is not a systems approach centered on the aircraft system.

Instead the system manager manages each modification in accordance with its degree of progress through the process. Thus a modification to a radar set may be in the same category as a modification to an engine, or landing gear, simply because all three are in the early planning stage. There may be other radar modifications in the system, some of which are being installed on the aircraft, some in development, some perhaps working through the funding process. Interviewees have said that good system

managers try to group modifications according to type--that is, several radar modifications in one group--when there is more than one modification planned for a particular subsystem. However, the rigidities of schedules, the inflexibility of the system once a modification has been approved and bought, the vertical information structures of the system, the tendency to pursue the solved problems, and the depot and system manager workloads all conspire against these attempts.

One example of how the inflexibilities of the system work against a coordinated systems approach to modifications shows up in the source of all Class IV modifications, deficiencies. As was explained in the Class IV requirements/capability subsector, Class IV requirements come from deficiencies in the aircraft system. What is not included in that subsector is the psychology of the system that collects the deficiencies in the material improvement projects (MIP). According to Dugas and AFR 57-4, all deficiencies must be documented in a MIP, and all Class IV modifications must have a MIP history (14; 22). The problem is that the number of the engineering and technical positions authorized to manage MIPs is based upon the number of MIPs <u>closed</u> each quarter. This creates pressure to open and close a MIP quickly, which results in a modification request that may never have been considered in terms of its effect on the overall aircraft system.

Again according to interviewees, many system managers have no grand strategy or plan for the aircraft--no ultimate configuration goal. Some aircraft, like the F-4 for example, have so many configurations and so many modifications going on in the field and in the depot that no one can identify all the configurations. Even when the paperwork has stayed with the individual aircraft it started with, an audit of the configuration would identify discrepancies between the aircraft and its papers (10).

A simple example demonstrates how a system and its modifications can quickly get out of control. As figure 3.1 illustrates, concurrent modifications that start at different times and build on one another can set the stage for chaos in configuration control. If a modification is cancelled, or delayed, or stopped midway through implementation on the aircraft, the potential confusion increases. Since some modifications depend on changes made by a previous modification, the absence of the earlier modification will cause the later modification to either change or be installed in two versions. In the illustration MOD C was stopped midway through implementation. Since MOD E depended on an aircraft configuration that included some of the changes made by MOD C, two versions of MOD E are now required. At least two configurations of the aircraft must now be tracked for the useful life of the system. Ccmplicating the story further, aircraft are usually

```
+----------------------------------------------------------------------+
:   Time . . . . . . . . . . . . . . . . . . . . . . . . . . . . .     :
:        |Baseline configuration production|                           :
:   MOD A          |Base + A                         |                 :
:   MOD B             |Base + A + B                    |               :
:   MOD C                |Base + A + B + C               |             :
:   MOD D                   |Base + A + B + C + D          |           :
: MOD C stopped                 |Base+A+B+C+D |  Base+A+B+D   |        :
:   MOD E version 1 (C)         | Base+A+B+C+D+E |                     :
:   MOD E version 2 (no C)                   |Base+A+B+D+E    |        :
:                                                                      :
:PDM cycles          |  1  |  2  |  3  |  4  |  5  |  6  |  7  |       :
+----------------------------------------------------------------------+
```

Fig. 3.1 Effect of Modifications on Configuration Baselines

modified when they are scheduled to enter the depot for periodic depot maintenance (PDM). If a modification begins implementation during the middle of a PDM cycle, then it will not be implemented on all the aircraft in the inventory until the aircraft missed in the beginning of the cycle return for the next cycle. This means that every single aircraft must be tracked for every single modification scheduled to affect it. Add to this simple example the dozens--or even hundreds, on some aircraft types--of modifications in various stages between initial recognition of a deficiency and incorporation on aircraft, and the sheer magnitude of the management task begins to emerge.

Top management visibility into this everyday problem of interdependent modifications tends to occur only when some large, already visible modification encounters an expensive change due to a situation like the fictitious MOD C in the illustration. This point was brought up by a deputy

assistant secretary of the Air Force, who then wondered what policy he could establish to eliminate the problem. His concern about the problem was shared by other top managers, none of whom could pinpoint the exact reason for the problem nor any solution to it. They see only the tip of a very large iceberg. After developing the model of the process, however, it seems that the problem, and potentially, the solution, lies in the structure of the approval process for Class IV requirements, the management of Class IV and V developments, and the production (which includes implementation) of all modifications.

As was discussed earlier in this section, the systems approach to management attempts to look at the system of interest (the aircraft system, in this case) as a whole, recognizing the interactions and interdependencies among the subsystems. Also discussed previously were the current symptoms of management problems experienced by the managers of aircraft modifications. The problems appear to originate with the method of approving Class IV requirements, the communication of intentions to install Class V modifications under development, and the planning and control of the aircraft configuration in the day to day management.

Class IV requirements, development and approval is depicted in figures 2.2 and 2.4. The earliest stage of the development of the requirement, the collection of deficiencies, is affected by the MIP process as described in this

section. Once the MIPs are opened, they can be closed only by an accepted solution, which may be a modification or some other solution like a maintenance change. The solution is accepted by the ALC configuration control board (CCB) for a modification solution under $2 million, by HQ AFLC's CCB for modifications over $2 million but under $10 million, and by USAF for modifications over $10 million. The CCB, whether at the ALC or HQ AFLC, considers only the modification proposal at hand, not how it will fit into ongoing and planned modifications. At no time are problems without current solutions considered against the "solved" problems to examine whether more resources should be directed to the unsolved problems (the exception is safety problems that are solved regardless of the difficulty involved). In fact, another major issue centers on the fact that requirements never go through an approval process before the search for solutions begins.

One more aspect fills out the picture. The ALCs are chronically short of engineers and technicians, and only minimally funded with sustaining engineering money. These are the two resources required to develop solutions to the tough problems. Either the technical people must be available to engineer a solution themselves, or the money must be available to contract with some outside firm to develop a solution. If neither one is available, the only remaining choice is to request the original aircraft contractor,

who normally is on some sort of support contract, to submit an ECP for the solution. This effectively solves the problem, but it also essentially eliminates any potential for competition for better solutions or prices.

With the pressure exerted by the manpower measurement system to close MIPs, the CCB's willingness to approve solutions, and the shortages of technical people and funds, the lack of a grand plan or a systems approach to management of the aircraft modifications guarantees that problems like the many configurations of F-4 aircraft will result.

Pressures exerted by Class V modification development problems further exacerbate the control problem. As the development sector (figure 2.10, 11) illustrates, the amount of cross-command interaction required and supplied affect the effectiveness of the management of the development effort (usually by AFSC), and drive the cycle time for the development and the firmness of the design baseline when the modification enters consideration for production. As already demonstrated, delays in expected modifications and changes to the design baselines can cause ripple effects through the entire aircraft inventory. If AFLC was not involved in the design of the Class V modification at the beginning, and continuously, the aircraft configuration baseline to which the Class V was designed may bear little resemblance to the current baseline of the aircraft. This makes the need for a systems perspective in both AFSC and

AFLC clear. AFSC managers of the Class V development are trying to develop a modification to go on many systems, all of whose baselines may be changing. AFLC aircraft system managers are trying to juggle current and other planned modifications with an unstable schedule for the Class V modification. Without constructive interaction throughout the process, many iterations will be required to pull the Class V modification and the aircraft together. Effective interaction becomes even more difficult when the AFLC managers are denied funds for traveling, or are forced to choose between spending funds on solving current problems or spending funds to plan to avoid future problems.

Much the same problem is evident in the production sector (figure 2.12, 13). Here the interaction between the commands tends to focus on solving the problems that resulted from insufficient interaction during development. If the problems are significant, modifications (whether Class IV or V) may begin implementation late in order to accommodate the changes required to bring the modification kits up to a standard configuration capable of being installed. Again, as with all the other influences, this ripples throughout the entire aircraft inventory and modification schedule.

After this discussion, it is evident that the current structure of the modification process fosters some undesirable behavior. In particular, the structure encourages

solutions to the easy problems, discourages the systems approach to aircraft configuration control, discourages competition for solutions to deficiencies in the system, increases the likelihood of loss of configuration control of aircraft, and perhaps most basic of all, never considers requirements for validation prior to having a solution in hand. Safety requirements, again, are an exception. A summary of this section together with recommendations will be presented in the next chapter. The next section will analyze the Class IV requirements approval process.

Class IV Requirements Approval. The second key issue area found during the development of the conceptual model centers around the approval of Class IV requirements. In order to appreciate the issue of Class IV requirements approval, the process used to approve Class V requirements will be reviewed.

As with any other requirement for new capability, Class V requirements are generated in response to some deficiency in capability. After the deficiency, or need for new capability is identified, the requirement is documented more or less formally (depending on the anticipated cost). Once the requirement is documented, it is approved by the using command, or Air Staff (again, depending on anticipated cost), as a valid requirement which is not being satisfied by any other means underway or planned (at least so far as is known by the validating group). After the requirement

is validated, or at least after it is documented, the search for a solution begins. On occasion a solution is known or may even be specifically isolated and ready to be used. Even so, the person selecting that solution must be able to justify it as the best one for the need.

The requirements process for Class IV requirements is very different. As was described in the last section, the collection of deficiencies into MIPs is the equivalent of the development of the need in the Class V process. But, once a MIP exists, the only way to close that MIP is by an approved solution. That is, given the existence of a MIP, the engineers and technicians immediately begin the search for a solution. Since the existence of their job positions depend on the number of MIPs closed in a quarter, it can be expected that opening a MIP occurs with little challenge to the validity of the deficiency or requirement. Instead, it would tend to receive considerable effort directed at finding a solution.

Once a solution is proposed, whether by modification or otherwise, the first review occurs. This review, by the CCB at the ALC, examines the solution in terms of the deficiency and approves or denies it. If the dollar value of a proposed modification is over $2 million, the command-level CCB must also approve it. Otherwise, the only higher level review it receives is at the beginning of the budget cycle. At that time, as described in Chapter II, budget

analysts from HQ USAF and AFLC visit each of the ALCs to review all the proposals for Class IV modification new starts. At that time the analysts review the requirement and the proposal for the modification, but it is not necessarily part of the review to ask whether the modification is necessary, or the requirement is valid. This can result in doing a modification while missing another deficiency which renders the original modification ineffective at best. An example is the radio on the FB-111. A Class IVC modification was proposed to replace the radio. The old radio had 80-100 hours mean time between failures (MTBF), while the new one (off the shelf) would provide 5000 hours MTBF. However, the FB-111 was constrained to one to two hour missions because the navigation radar had an MTBF of 1.9 hours. The 4900 hours added by the new radio would be worthless (36).

If a deficiency creates a hazard to people, equipment, or the aircraft, then the safety aspect of the deficiency will cause the modification proposed to fix it to have the highest possible priority of all modifications. If the solution to the deficiency is not apparent, then the safety deficiency will be worked around by other means until a solution is found. If the consequences of a safety deficiency are bad enough (like grounding all of an aircraft type), more resources will be devoted to finding a solution.

For non-safety-related modifications, the likelihood of the modification being approved depends more on the availability, or readiness of the solution than on the gravity of the deficiency. To emphasize that point, the weighting technique in the modification priority model is revealing. The highest possible weight, 6.0 points, is assigned to a safety modification. The user's priority for the modification, at the highest, can reach 0.75. But, a modification whose status is tentative, versus budgetary, gets 3.0 points. Then, for each step completed of the solution process, it receives additional points in its priority index. A total of 4.25 points could be assigned to the index if the manager with the deficiency has received the ECP from the contractor, developed the change, completed the trial installation, awarded the contract to implement it, and kit-proofed the modification.

The point is not to criticize the modification priority computer program, but to highlight the emphasis the system places on solutions. This emphasis continues throughout the review process for Class IV modifications, and also for Class V modifications for which requirements are approved and the development work, if any, is largely complete. Even at the DOD level, there is an analyst for modifications who will drop a request for funds to solve a deficiency out of the funded level if no modification solution is in hand. It appears that funding for the purpose of

developing a solution to a difficult problem is almost impossible. Thus the point is that a solution is a prerequisite for approval of a Class IV modification.

Three results obtain from this emphasis on solutions. First, since the requirements are never questioned, no consideration is given to whether the requirement is valid. There may be modifications being implemented which have no real requirement. Second, since the solution must be in hand, no real emphasis is placed on considering alternative modification solutions. Alternatives _to_ modifications are considered and frequently used, which is appropriate. But once a solution is chosen, especially to the smaller deficiencies, the advantage of solution av ability can outweigh consideration of other potentially better solutions. Third, since the more difficult deficiencies may be beyond the funding or time available to devote to finding solutions, the aircraft contractor virtually is assured of being awarded the contract to modify the aircraft to repair the deficiency. Again, as described in the previous section, if the engineers and technicians are faced with a too-tough problem, and limited funds to devote to finding a solution, the only alternative remaining to them is to ask the aircraft contractor to submit an ECP to the support contract. This legitimately enables the contractor to submit a solution to the problem before any other contractor even knows about the problem. Then, with an ECP in

hand, pressure grows to accept that solution rather than to go looking for some other solution. Effectively, this eliminates any potential for competition for solutions to Class IV requirements. In addition to these three results, the lack of a requirements review and validation process further hinders any attempts to approach management of the aircraft system with a systems viewpoint.

AFSC/AFLC Split Management. The third key issue area focuses on those aspects of the aircraft modification process in which management control is split between AFLC and AFSC. Most of the split management is modeled in the development management (figure 2.11) and production management (figure 2.13) subsectors. In both subsectors the amount of cross-command interaction required influences the overall level of management effort required. The ownership of the aircraft, on the development side, and the degree to which configuration control is split, on the production side, represent the division of management control between the two commands.

There are two main elements of this issue. The first concerns the requirement for involvement of the logistics support community in the early design stages of development of any system, whether it is a Class IV or V modification or a new acquisition. The second element involves the situation where the two commands must share configuration control of an aircraft system while a particular modification is being installed.

The general need for the logistics support community to be involved with the development process early in the design stage is well recognized. Its importance has been emphasized by the establishment of the Air Force Acquisition Logistics Division of AFLC, and the Air Force Acquisition Logistics Center of AFSC. The importance of designed-in logistics is stressed, and the highest levels of management that review the progress of development now require discussion of logistics support planning (19; 20). Relatively unrecognized are the special logistics problems that arise when a newly developed subsystem, or newly developed integration of an off-the-shelf subsystem, must be installed on temporarily deactivated operational aircraft.

When a new aircraft is entering the inventory, no existing support system is disrupted. If baseline changes continue after deployment, even after deployment of the military support capability, there are disruptions, but the entire logistics and operational system is geared up to receive the new aircraft and support system. The total operational capability of the Air Force is being increased with the addition of each new aircraft. The changes cause problems, but the problems are limited to the base receiving the system, of which there are usually only a few in the beginning. If on the other hand, a Class IV or V modification kit is still undergoing changes as it is being installed, the consequences are far more damaging. In this

scenario, the operational capability of the Air Force is being temporarily reduced as each aircraft is drawn down from operational status to allow installation of the modification. Furthermore, the aircraft come into the depot from all operational bases, so if they return to duty with several configurations of a modification installed, the logistics support system is simply unable to cope. Interim contractor support must then fill the void. It is difficult enough to upgrade the support system with each base's mix of modified and unmodified aircraft changing constantly. The additional burden of multiple configurations of the modification is unsupportable.

AFLC has attempted to solve the problem by deferring proofing of a new modification kit until the first production kit has been delivered. After the kit is proofed, the support plans are approved and then can enter production as well. This effectively reduces the number of configuration changes that ripple through the operational support system. Unfortunately, it also increases the amount of time from inception of the modification to final installation with a fully operational support system.

The discussion above describes the differences between logistics support planning difficulties for new acquisitions versus modifications in the relatively simple situation in which AFSC turns over the modification kit and support plans to AFLC for installation. These difficulties

become greater when AFSC installs a modification on an aircraft that normally is under AFLC configuration control. In this situation, the system manager, who at all times is involved in planning for and installing numerous modifications (as discussed previously), must relinquish to the AFSC program manager the right to accept or reject changes to the aircraft, or at least the part affected by the AFSC modification. The AFLC system manager does not, however, relinquish control over all the ongoing and planned modifications that AFLC will install. This split configuration control violates the principle of configuration management that gives a single manager the unilateral authority to accept or reject configuration changes.

With control split, those AFLC-controlled modifications continue to be set up and installed before and during the installation of the AFSC-controlled modification. During this period of time no one has final say over potential changes to the configuration baseline. AFSC may not realize that changes continue to be installed on the aircraft throughout the AFSC development of the modification. The result is that AFSC designs the modification to the aircraft's configuration baseline at a point in time. Along with the design of the modification, AFSC may design some changes to the aircraft to accommodate the modification. Meanwhile AFLC continues to physically change the aircraft configuration with its new and continuing modifications.

When the first modification kit arrives, severe consternation accompanies the discovery that the modification kit can not be installed into the aircraft because the kit baseline does not match the aircraft baseline. The more significant, costly, and visible the AFSC modification, the higher will be the level of review of the problem. Although no specific examples were cited, the Principal Deputy Assistant Secretary of the Air Force for Research, Development, and Logistics stated that he sees briefings on these problems frequently (8). Considering that only the big problems reach that level, there must be many more that are resolved at lower levels.

Part of the reason for this problem lies in the different missions and resulting management philosophies of AFSC and AFLC. AFSC's mission, briefly, is to research, develop, and acquire new weapon systems for the Air Force. Research and development tend to progress fitfully, with problems along the way that slow the progress and increase costs. Managers with creativity and flexibility succeed, and take pride in developing the best possible system for the available money. Changes in the configuration are common as testing reveals faults and the contractors develop solutions. The impact of changes on existing operational systems is usually zero. Written procedures for the work of AFSC generally don't exist, because most situations are new and unpredictable.

AFLC, on the other hand, has the mission of supporting and modifying operational systems. It rewards managers who excel at controlling repetitive tasks like ordering parts, supervising repair lines, and scheduling aircraft for periodic maintenance. Nearly every such task has written procedures that define its nature and management. Little is left to chance and most situations are predictable. The level of activity is very high and subject to urgent pressure from the operators. Little time is available for long range planning and strategy. The goal is to keep as many systems flying as possible.

With differences as great as those described, naturally AFSC and AFLC have built-in problems in communicating. AFSC feels no pressure to limit or resist changes to modifications it is developing while AFLC perceives every change as a threat to operational availability. AFSC views schedule slips as regretable but sometimes necessary to provide the best system. AFLC, in contrast, would prefer a less complex system that is delivered on time and that works. Comparisons like this can continue, but the point is that AFSC and AFLC don't understand each other's thinking. The result is frequently distrust of the other.

The combination of these two elements of split management is higher costs, longer cycle times to incorporate modifications, and greater distrust between the two commands. The higher costs result from delays and rede-

signs due to missing or incomplete communication. The longer cycle times result from the combination of extra time required for redesign and the delays imposed to minimize changes after production begins. The greater distrust results from the failures of communication, the lack of understanding by each command of the differences between them, and differences in the goals and organizational structures of AFSC and AFLC. This greater distrust leads in turn to more problems like those discussed in this section.

Priority Decisions by Resource Allocation. The fourth key issue area concerns the way in which priority decisions about modifications are made. The analysis shows that this issue is directly related to the second issue, which dealt with the absence of a requirements approval process for Class IV modifications. This section presents the specific analysis of the resource allocation process and addresses its structural bases.

The financial sector is involved in resource allocation from the submission of the requirement for funds to the release of approved funds. As part of their role, the Air Force financial community analyzes the accuracy of estimates, the correctness of the funding profiles, and the completeness of the funding request. Correctness of the funding profiles refers to the phasing of money over the years in accordance with the expectations for spending it.

The many years of experience of the financial analysts have provided them with the ability to judge the reasonableness of and likelihood of successfully executing spending plans. Completeness refers to ensuring that what has been requested will cover all aspects of the work it is meant to fund. For example, budgeting for a modification requires not only procurement funds with which to buy the kits, but also operations and maintenance funds to install the kits and provide for the transition support costs. The financial community also supports the process of ranking budget requests by repricing or cutting requests as required, and ensuring that an executable program remains after such changes. After the funds are approved by Congress, the financial community then allocates funds in accordance with the amounts approved for each project, disburses them to the organizations tasked with each project, and oversees expenditures to assure the funds are spent for the designated task in a timely manner. In the case of the smaller Class IV modifications, the funds may be spent for the originally approved modifications or for entirely different modifications (which were also approved, but not funded per se), if the requirements change, or the problem is otherwise solved.

The role described clearly places the people in the financial sector in a position of knowing most of the important elements of a program's financial workings.

Because of the requirement to tie tasks to the funds, the financial community becomes very knowledgeable about the primary goals, tasks, and problem areas of programs. In fact, it became quite apparent during the interviews that the segment of the financial community that handles modification funding knows more about the modifications programs and their history than does the operational community which is involved in the requirements approval and ranking process. In this last point is the source of the fourth issue.

The role of the user in the requirements process is to identify deficiencies and new capability needs, and to rank the modifications proposed to resolve those deficiencies or provide the new capability. At some level (depending on the magnitude of the deficiency or need for capability), each requirement should be reviewed and validated. As described in the second key issue, Class V requirements are validated and ranked in this way. The Requirements Review Group at HQ USAF is responsible for validation of these requirements. Priority ranking is first accomplished at each of the major operational commands (MAC, SAC, TAC), and then combined into a single ranked list by the modification review group at HQ USAF (46). If for some reason the requirement changes or is otherwise solved, the statement of need is cancelled and the funds returned to HQ USAF for reprogramming.

For Class IV, however, requirements are not reviewed beyond the level of the ALCs unless the user is heavily involved in some particular requirement (which is the exception). Requirements are transformed into modification proposals at the same level where the requirements are generated. It is easy to see how the requirement and the modification that results from it get combined such that approval of the modification is equated with approval of the requirement. As may be recalled from discussion of the Class IV requirements approval process, the modification is reviewed by the CCB, which considers how the modification solves the need, not whether the need is valid. Then it is reviewed by budget analysts from HQ AFLC and HQ USAF. If it is approved, the modification proposal enters the priority ranking system. HQ AFLC initially ranks the modifications, creates the PDPs, and sends the entire package to HQ USAF. HQ USAF reviews the modification PDPs and the ranking, and after any changes, enters the approved ranked modifications into the Air Force POM process. If, after the funds are approved, the requirements change or are resolved by other means, the budget analysts in the modification office at HQ USAF reassign the funds to other approved modifications. Dollar amounts are not specifically tied to individual modifications.

This process seems to work very well. The issue does not center around how it works, but around the fact that

the financial community rather than the operational community ranks the modifications into priority order. A somewhat compensating factor is that AFLC is considered the user for support elements. Also, most Class IV modifications are low cost, maintenance or support oriented modifications. Nevertheless, the major using command is not directly involved in deciding which modifications should be funded first. Furthermore, at HQ USAF the requirements community holds no formal review of the ranking of Class IV modifications. Therefore, the decision of the financial community determines the priority of modifications, and therefore determines what gets funded.

Because the knowledge and dedication of the specific people involved is so great, it is doubtful whether the requirements community at HQ USAF could significantly improve on the ranking achieved by the financial community. This places a tremendous reliance on specific individuals. It also tends to favor funding quick solutions to problems rather than funding a search for what might be a better solution. Finally, this process places considerable control over the Class IV modifications into a single sector of the overall modification process. The requirements and modifications are developed at the ALCs, but from that point until actual purchase of modification kits the financial community controls the process.

Large modifications get more visibility in the overall budget process because they are placed in individual PDPs. The small modifications in the Class IV modification PDP receive little or no attention outside the USAF financial community. Thus, it is really the small modifications and the unsolved problems that are affected fully by the financial community's processing. Large modifications are only really subject to total control by the financial community when they are undergoing the initial approval review at the ALCs. Repeated deferrals in that review can keep any modification from being pursued for many years by simply declaring it "not ready." This delaying technique, called retrograde analysis, can effectively prevent a modification, large or small, with or without user support, from ever being funded. Yet the technique avoids direct confrontation. In the absence of a requirements approval and user ranking process, modifications can be prevented from ever leaving the ALC level.

This section discussed the issue of the financial community ranking Class IV modifications through the resource allocation process. This is something of a default position for the financial sector because the operational community does not get involved--apparently by choice, at least at the HQ USAF level. The results include a well-run process in which financial experts make requirements decisions, modifications are approved but requirements never

are validated, and the modifications funded may not be the modifications installed. Modifications are viewed alone, which is part of the issue earlier concerning a systems approach, with the emphasis placed on doability.

Personality Driven Process. Frequently in discussion about the modification process, interviewees commented that the process is totally personality driven, and then they predicted that various segments would either improve or disintegrate if the strong individuals vanished. In order to progress, every process or organization depends on the people who work in it and manage it. It seems that the more removed the organization is from hard production, the more people-dependent are its operations.

The modification process clearly fits into the people-dependent end of the continuum since even the lowest level in the process (as bounded in this study) works not with actual production of modifications but with such management problems as contractor interfaces, budget preparation, report preparation, and modification proposal development. Given that the modification process is on the people-dependent end of the continuum, the next concern is a two part question. First, are the management procedures and controls built into the process sufficient and appropriate, and second, are there adequate and appropriate selection procedures and training programs employed to ensure qualified people fill critical positions? In other words, the

process should be sufficiently guided by procedures and personnel policies that the impact of changes in personnel are minimized. The organization should not drastically change, nor its activities grind to a halt with the departure or replacement of one individual. Of course, some impact is inevitable. As figure 3.2 shows, the quality of job performance increases over time as the person in the job learns the job and gains experience. A sharp drop in performance accompanies the replacement of the first

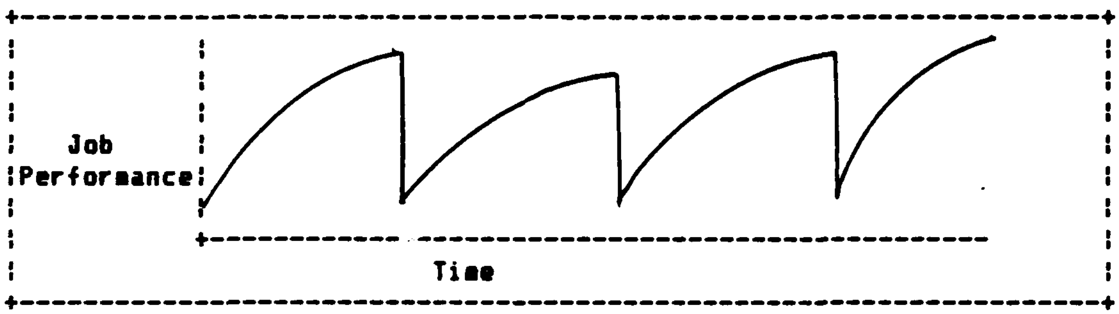

Fig. 3.2. Job Performance by Successive Incumbents of a Job

individual, and the second then improves in the same way as the first, with some individual variation (23). The purpose of personnel selection standards and procedures is to reduce the depth of the drop in job performance over the transitions. Training then helps decrease the time required to return the level of job performance to an acceptable level. Some individual variation will always play a role, but good selection and training should minimize the undesirable variations and capitalize on the desirable ones.

No direct investigation in this research examined personnel selection procedures or training. Several interviewees said, however, that the quality of people at all levels of the modification process is very uneven. Some system managers were described as good people without training, others as unqualified. Similarly, SCOs, SYSTOS, and PEMs were characterized in terms or effectiveness, knowledgeability, and degree of interest or involvement. Some analysts because of their position and personality, have become critical assets. Without them, the credibility of the system comes into question. With them, the personalities in other positions, such as program managers, SCOs, SYSTOs, and PEMs become critical because meshing some of the personalities is required for effective accomplishment of goals.

Whether these situations are good or bad is not questioned here. The fact of their existence suggests that some of the structure of the modification process may not be sufficiently robust. In the area of training, for example, one interviewee said that the requirements for the job of system manager do not include any training on project management or the systems approach, which he felt severely limited the system manager's ability to grapple with the problems of major modifications. With the trend toward more modifications as a way to improve capability, this could become a critical limitation. In the area of

credibility, it was said by another interviewee that the process itself has very little credibility, but that certain individuals had total credibility. This suggests that the structure of the process either lacks clarity for outside understanding or else it depends too much on the capability of individuals and not enough on its own procedures and policies. This latter possibility is supported by several interviewees who commented that the process is so complex that anyone who could understand it could run it. The confusing melange of regulations makes matters worse with contradictory, out of date documents that, in some cases, have been in draft for years. With unusable regulations, reliance on the people who run the process becomes total.

This section discussed the issue of the modification process as personality driven. It accepted the dependence on people in the process, but suggested the significant variations caused by inadequate training and selection were not acceptable. It also suggested that the credibility of the process totally depended on the individuals who run it.

Summary

This chapter discussed the validation of the conceptual model presented in Chapter II and presented the five key issues discovered during the study. The key issues were the management approach to modification of aircraft, the approval process for Class IV requirements, the management

complexity associated with split management, and the personality dependence of the entire modification process. The next chapter summarizes the study, presents conclusions about the aircraft modification process, and discusses some recommendations relative to the process.

IV. Summary, Recommendations, and Conclusions

Introduction

In this final chapter the research effort is summarized and conclusions are drawn. Recommendations resulting from the analysis and conclusions are presented, and use of the model is discussed.

Summary and Conclusions of the Study

The major purpose of the study was to capture the significant aspects of the Air Force aircraft modification process and present them in a form that can be used to amplify the experience and judgement of the decision-maker when critical decisions are being made. This purpose was achieved by use of the system dynamics approach to analysis. The literature of regulations, studies, and reports that examined the modification process was studied, and key decision-makers and experts in the process were interviewed in the first of a two part interview sequence. These sources provided the basis for a conceptual model of the aircraft modification system, which was presented in Chapter II. The model was validated during its development with the aid of the Turing-test method. In a second set of interviews, experts and key members of the process were asked to examine the model and identify flaws and suggest corrections. The result was a validated conceptual model

of the aircraft modification process. While such a model could be quantified for the aircraft modification process, this step was judged unnecessary, and possibly undesirable, relative to the central purpose of the study.

The conceptual model is divided into four major sectors, with one or more subsectors each. The model traces the process through the continuous cycle of requirements generation and approval, budget requests, approval and allocation of funds, development, and production and implementation of the modification. The result of this cycle is the restoration or increase of capability of the aircraft. In the requirements sector, the Class IV requirements/capability subsector models the generation of deficiencies which become requirements, and then are transformed into modification proposals. In the Class IV requirements approval subsector the modification proposals are approved for entry into the funding process (there is no requirements approval process per se). The Class V requirements/capability subsector traces the development of the requirements from changes in the threat, and the Class V approval subsector models the approval of those requirements.

In the financial sector, the requests for funds for modifications proceed through the Planning, Programming, and Budgeting System (PPBS). The Air Force financial subsector scrubs the requests, and for Class IV, ranks

them. The operational community ranks the Class V funding requests. The DOD financial subsector processes the development of the DOD budget request, and builds the President's budget request. It combines the modification funding requests with other defense programs in the President's budget request. The external financial subsector examines Congressional enactment of the budget in terms of modifications and allots the funds to the development and production sectors.

The development sector, with its management subsector, explores the process of developing Class IV and V modifications. The key players, AFSC and AFLC, and their interaction are important in this sector. The production sector examines the forces that influence the production and implementation of modifications on aircraft. Again, the interaction of the two key players is important. The production management subsector, like the development management subsector, explores the management aspects in depth.

Study of the structure and relationships in the model combined with the analysis and comments of the interviews generated five key issues regarding the modification process. These issues drive the behavior of the model and the course of the actual modification process. The first issue concerns the management approach used in the aircraft modification process. The circumstances are ideal for appli-

cation of the systems approach, but it is not being used. The consequences are a fragmented process, a lack of long range planning, confusion because of the many configurations of aircraft, duplication of repairs, missed opportunities for combined modifications, and increased cost to the Air Force.

The second issue centers around the Class IV requirements approval process. There essentially is none. Unlike Class V requirements, no review group or procedure examines the requirement separately from the modification proposed to resolve it. Hence approval of the modification proposal constitutes approval of the requirement. Approval of the modification hinges on availability of the solution. The consequences include solution of easy problems rather than tough ones, no assessment of the relative importance of problems, and essentially no opportunity for competition for alternative solutions to problems.

The third issue concerns the management complexity caused by split management of modifications between AFSC and AFLC. Difficulties in communicating between the two commands are caused by their different missions and resulting management philosophies. These difficulties are exacerbated by the lack of understanding of these differences. The effect of this situation is distrust between the two commands, and frequently problems with modifications which do not fit into aircraft or whose baselines are still changing, making them unsupportable.

The fourth issue is a direct result of the lack of a Class IV requirements approval process. It centers around the fact that Class IV modifications are ranked in priority order by the modification budget analysts, not by representatives of the operational community. The quality of the ranking is not questioned. Rather, the concern is that ranking by the financial community tends to favor solutions that are ready rather than solving the most important problems, and places into the financial community almost total control over which modifications are pursued.

The fifth issue addresses the question of whether the modification process is too driven by personalities, or strong individuals. That the modification process naturally falls into the people-dependent end of the management spectrum is accepted. The weaknesses in the process appear to exist in the selection and/or training procedures for the lower level managers, and in the actual structure of the process at the higher levels. A total dependence on specific individuals for the credibility of the modification process suggests that the process is not understood or lacks credibility inherently.

These five issues together with the recommendations that follow resulted from the collection of information and the development and study of the conceptual model of the aircraft modification process. Based on the validation by the experts and decision-makers in the modification

process, the model fairly represents the aircraft modification process. As a tool, it is suitable for use by anyone to increase understanding of the process, and can be used by decision-makers to consider the effects of potential changes in structure or policy.

Recommendations for Changes

After consideration of the five issue areas, which were summarized in the previous section, two types of recommendations result. The first type suggests changes in the modification process itself. These recommendations include both structural and policy changes. The second type recommends further research to extend and improve the precision of the model. The recommendations for changes are listed and discussed in the next section. In the following section, the recommendations for further research are presented.

There are five recommendations for changes to the modification process that result from this study. They generally follow the structure of the key issues detailed in Chapter III and summarized in the last section. Most of the recommended changes are general in nature, providing directions of change rather than specific, detailed, ready-to-implement changes. The five recommendations are listed below, and then discussed individually.

As a result of this study, it is recommended that the Air Force:

1. Establish a requirements review process for Class IV modification requirements in the operational community which then is reviewed in the HQ USAF requirements community;
2. Establish a Class IV modifications ranking process to be run by the operational community in conjunction with AFLC;
3. Encourage a systems approach to management of operational aircraft by establishing a "roadmap" monitor for each aircraft system;
4. Improve understanding and credibility of the process by
   A. Updating regulations to the current DODD 5000.1 standard;
   B. Establishing mandatory training programs for managers involved in modifications;
   C. Including in training programs AFSC and AFLC philosophies and missions;
   D. Eliminating split configuration control during modifications;
5. Encourage competition for alternative solutions to requirements by
   A. De-emphasizing solution availability as a prerequisite to funds approval;
   B. Implementing the first two recommendations;
   C. Allowing AFLC to study alternatives contractually, either with development funds or by subcontracting to AFSC.

Individual discussion of the five recommendations appears in the following paragraphs. This discussion draws on the analysis of the issues provided in Chapter III.

As was discussed in the problem analysis and summarized in the last section, there is no formal requirements review and approval process nor ranking of Class IV modification requirements by the operational community. Establishing such processes, as the first two recommendations suggest, would allow examination of the requirements for which no

solution has been determined. This would permit a conscious decision to either defer the search for a solution or emphasize the search while deferring other less important or less significant modifications, thus reducing the tendency to favor the easily solved problems. It would also involve the operational community in the determination of priorities.

The third recommendation encourages a systems approach to management of operational aircraft by assigning a monitor to be responsible for each aircraft's "roadmap" or long range plan. This long range plan would track current problems, current and planned modifications, and efforts underway to solve current problems. It is suggested as an approach to resolving the first issue. The complexities of management of operational aircraft demand some long range planning tool, but the current system does not require or lend itself to the systems approach. The level of such a monitor is not suggested here. It could be the current system manager, if training on the systems approach is provided and job performance is graded based on that roadmap as well as current responsibilities. It could also be an individual at the operational command, or at HQ AFLC, or at the HQ USAF level. The key point, though, is that this monitor be required to manage by, and report on the basis of, a long range plan for the aircraft system. This systems viewpoint together with an operationally managed

requirements review process and ranking of modifications has the potential for easing the task of the system manager and introducing some structure into the complex Class IV modification process.

The fourth recommendation draws on discussion throughout the problem analysis, particularly that regarding the problems of split management between AFSC and AFLC, and of over-dependence on specific individuals in the process. The recommendation seeks to improve understanding of the process among those who work with it, and improve the credibility of the process among those who receive its output. In order to do this several policies should be established, all of which fit within the current structure. Updating all the regulations which govern the modification process so they reflect the current versions of DODD 5000.1 and DODI 5000.2 would provide those working with the modification process with an authoritative source. Currently the only way to find out what to do or how things really work is to ask one of the current experts. Establishing training programs which specifically concentrate on the modification process would allow promulgation of the desired way of doing things more quickly and efficiently. Including in those training programs material which explains the missions and management philosophies of AFLC and AFSC, preferably in classes which include people from both commands, would increase understanding of each other's problems and

potentially reduce the distrust between the commands. Finally, allowing the configuration control of aircraft to float between two managers should not continue. Once the aircraft responsibility has transferred to the system manager in AFLC, it should remain there. If configuration control must transfer back to AFSC for some reason, then so should management of all the ongoing modifications. Planned modifications would then be deferred or transferred as well. If the system manager retains control of an aircraft for which AFSC is developing a modification, then AFSC should present changes to the system manager's CCB, not hold a separate CCB. All of the parts of this recommendation offer the potential for significant reductions in the confusion that currently surrounds the modification process.

The fifth recommendation derives from elements of all the issues. It became apparent that the structure of the process, with its emphasis on solutions to Class IV deficiencies, eliminated any possibility of competition for modifications. The lack of a requirements approval process, and the absence of the operational community in the ranking of modifications for funding priority created the structural climate for this emphasis. The chronic shortage of technical people and funds with which to research alternate solutions leaves the system managers reliant on the aircraft's original contractor. To

encourage competition, then, the first two recommendations should be in place, the availability of solutions should be de-emphasized, and AFLC must be provided some way to study alternatives outside its own organization and the aircraft contractor. Whether this is supported by providing development funding to AFLC, or by setting up procedures to enable AFLC to subcontract such work through AFSC is not as important as finding some way to give AFLC an alternative to its current constrained situation.

Of the five recommendations presented here, the first three are structural and the last two are policy suggestions. None should be taken as criticism of the people in the process. Without them, nothing would be getting done at all. These suggestions are offered as ways to ease the jobs of all who work in the aircraft modification process, and as ways to increase the effectiveness and efficiency of the process.

This completes discussion of the first type of recommendations, which suggested changes in the modification process. The second type of recommendations, which suggest further research to improve the model and increase its usefulness are presented in the next section.

Recommendations for Further Research

Work on this study has identified many areas for further study. Entire studies could easily be done on most. In this section, the second type of recommendations,

which cover these future research areas, are identified and briefly explained.

In the requirements sectors there are technology factors which influence serviceability in the Class IV requirements development, and the percent of the basic system affected by modifications in the Class V requirements development. While these factors are recognized as existing and influencing behavior, the means for measuring and collecting data on the factors is unknown. Future research might examine changes in ongoing programs that resulted from technology advances, and interview system and item managers to gather their experiences.

In the Class V requirements/capability subsector comparisons of the relative quality of weapon systems owned by the U.S. and by the Soviet Union are needed to determine the direction and size of the quality advantage or discrepancy. Comparing quality requires some insight into the design of the weapon systems and the resulting performance. A very fertile area for further study would be to determine how to achieve such insight and then quantify the comparisons.

In the financial sectors there are also many opportunities for further research. One is the relationship between financial constraints and the percent of the budget applied to modifications. The hypothesis used in this study was that as financial constraints become tighter, a

greater percent of the budget is devoted to modifications because greater increases in capability can be had for less money and less delay with modifications than with new acquisitions. In the same vein, if this reasoning holds up under research, then Congressional pressure to reduce the DOD budget should decrease as the percent of the budget devoted to modifications increases. There was some doubt among DOD analysts whether Congress really realized the difference of cost and schedule between modifications and new acquisitions. Interviews with staff members from the House and Senate Armed Services Committees, however, indicated their full awareness of the differences between modifications and new acquisitions. Their approval of modifications as a means for increasing capability was significant (30; 44). Similarly, the total size of the President's budget request, or at least the DOD portion of that budget request, affects the Congressional pressure to reduce the DOD budget. As the size increases, so also does the pressure to reduce the DOD budget. The exact nature of that pressure, the effect of the size of the budget, and even the way in which the size of the budget is represented require additional study.

Another fertile area for further research is the interaction between AFSC and AFLC - and the effect that interaction, or lack of it, has on the supportability and future modifications on a weapon system. Previous studies have

indicated that early involvement between the commands is mandatory to ensure proper consideration of support requirements, and to realize those requirements through appropriate design and development. None, however, have examined the results of early involvement on future modifications, nor really the effects of late involvement, or none, on the number and magnitude of modifications later installed by AFLC. As part of this subject, the role of TDY funding in the amount of interaction supplied, and the quality of interaction supplied should be examined. It appears that this seemingly insignificant element can be a determining factor in the effectiveness of modification management where substantial interaction is required.

In building the variable called effectiveness of development management effort supplied, several elements require additional research. The quality of managers supplied, and the adaptability factor (of the manager) particularly invite further study. The quality of the manager element includes, as indicated, the training and experience of a potential manager. Determining how best to measure and combine those elements must be discovered. The adaptability factor deals with the ability of the manager to balance the requirements of the user and its management with the development structure and management of the developing command and contractor, and then balancing those against the highly structured supporting commands. How to

measure this in managers, and represent it in the factors would be the goal of research in this area.

Use of the Model.

The model that resulted from this study can be useful in two arenas. First, future researchers can continue this study by deepening the understanding of the various elements and variables used in the conceptual model. Some greater depth was provided for variables in Appendix B. Verification of relationships between variables and determining the shape of the functions would further validate the model. Some quantification could then be useful to increase understanding of the process. It can also then be used to test changes in policy in a more rigorous manner.

Secondly, managers, policy-makers, and decision-makers can use the model in its present form to increase their own and their subordinates understanding of the aircraft modification process. It can then be used to develop or consider the effects of changes in policy, structure, or the effects of critical decisions. By using the model in this way, the recommendations presented earlier were developed. It is for this last purpose that the researchers hope the model will be used.

Conclusion

The purpose of this study of the aircraft modification process has been achieved. A conceptual model has been

created, and it has been judged by experts of the process to be a fair representation of the modification process it models. Thus, it has captured the significant aspects of the modification process. It was valuable for analyzing the modification process, and for assessing the recommendations presented in this chapter. Copies of the study will be provided to the numerous requestors, which will at least place the model in the hands of those who can use it. It is expected to provide a tool or decision aid to decision-makers in the modification process. Actual use of the study is, of course, beyond the control of the researchers.

Appendix A: Acronyms and Definitions

Acronyms:

AFIT - Air Force Institute of Technology.

AFLC - Air Force Logistics Command.

AFR - Air Force Regulation.

AFSC - Air Force Systems Command.

AIP - Acquisition Improvement Program.

ALC - Air Logistics Center.

BES - Budget Estimate Submission.

CCB - Configuration Control Board.

DG - Defense Guidance.

DOD - Department of Defense.

DODD - Department of Defense Directive.

DODI - Department of Defense Instruction.

ECP - Engineering Change Proposal.

FOC - Full Operational Capability.

FSD - Full Scale Development.

FY - Fiscal Year.

FYDP - Five Year Defense Plan.

IOC - Initial Operational Capability.

JTIDS - Joint Tactical Information Distribution System.

LSIC - Large Scale Integrated Circuits.

MAJCOM - Major Command.

MIP - Material Improvement Project.

MRG - Modification Review Group.

MTBF - Mean Time Between Failures.

OMB - Office of Management and Budget.

OSD - Office of the Secretary of Defense.

OSD/AC - OSD Comptroller.

PEM - Program Element Manager.

PDP - Program Decision Package.

POM - Program Objective Memorandum.

PPBS - Planning, Programming, and Budgeting System.

PRG - Program Review Committee.

RRG - Requirements Review Group.

SCO - System Control Officer (AFLC).

SON - Statement of Need.

SYSTO - System Officer (AFSC).

TCTO - Time Compliance Technical Order.

TDY - Temporary Duty.

TOA - Total Obligation Authority.

USAF - United States Air Force.

Definitions:

Aircraft Modification - A change in an airframe, component, or equipment that affects performance, ability to perform intended mission, flight safety, production, or maintenance (15:459).

Appropriations - Authority that permits Federal agencies to incur obligations and to make payments (38:85).

Authority to borrow - Authority that permits Federal agencies to incur obligations and to borrow money to make payments (38:85).

Classes of Modification - AFR 57-4 provides a descriptive breakout of modifications into five classes by rules and approving authority (see Class I-V descriptions) (14:3-6).

Class I modification - A temporary removal or installation of, or change to, equipment for a special mission or purpose.

Class II modification - A temporary modification to support research, development, or operational test and evaluation efforts.

Class III modification - Modifications required to insure production continuity.

Class IV modification - Modifications to insure safety of flight, to correct a deficiency which impedes mission accomplishment, or to improve logistic support.

Class V modification - Installation or removal of equipment changing the mission capability of the present system configuration.

Contract Authority - Authority that permits Federal agencies to enter into contracts or incur other obligations in advance of an appropriation (38:85).

Deficiencies - Consists of two types: (1) conditions or characteristics in any hardware/software which are not in compliance with specified configuration, or (2) inadequate (or erroneous) configuration identification which has resulted, or may result, in configuration items that do not fulfill approved operational requirements (15:207).

Development Engineering - Engineering effort required to get a new capability through the definition, design, development, intergration, testing, and preproduction qualification of a new item or through extensive redesign and requalification of an existing item. Development engineering is normally the responsibility of AFSC.

Dynamic problems - Problems that involve quantities which change over time and that incorporate the concept of feedback.

Engineering Change Proposal - A proposed engineering change and the documentation that describes and suggests it.

Feedback - The transmission and return of information. A feedback loop is a closed sequence of causes and effects, a closed path of action and information [26:3,4].

Hazard - Any condition that is a prerequisite to a mishap or an unplanned event or series of events that result in death, injury, occupational illness, or damage to or loss of equipment or property (2:2).

Materiel Deficiency - Any design, maintenance, material, quality, or software problem, inadequacy, failure, or fault. The Deficiency can result from inability to meet original baseline requirements (hardware, software, operations, performance, etc) or can be created from baseline changes which have evolved since the original baseline was established. Material deficiencies, in combination with the human, machine, environment, and mission elements, can cause hazardous conditions to exist (2:2).

Material Improvement Project (MIP) - Projects established by the implementing command program management office to document and control the investigation and resolution of known or suspected deficiencies of new systems and equipment. (15:432).

Mishap - An unplanned event or series of events that result in death, injury, occupational illness, or damage to or loss of equipment or property (2:2).

Modification (Mod) - A configuration change to a produced configuration item. Mods are categorized according to the level of effort required, the permanancy of the modification, and the capability change in the configuration item brought on by the modification. See the individual classes (Class I-V) for a description of these categories.

Policy - An accepted or settled way for approaching a problem, determined by appropriate authority and passed through guidance to subordinates. Each organizational echelon may thus establish policy when interpreting or providing guidance on policy received from higher authority [15:527].

Risk - An expression of possible loss in terms of mishap severity, mishap frequency/probability, and exposure (2:3).

Simulation - A technique used to describe the behavior of a real-world system over time. Most often this technique employs a computer program to perform the simulation computations [3:540].

System dynamics - A profession [or approach] that integrates knowledge (mostly descriptive) about the real world, with the concepts of how feedback structures cause change through time, and with the art of computer simulation for dealing with systems that are too complex for mathematical analysis [27:7].

Time Compliance Technical Order - Directives issued to provide instructions to Air Force activities for accomplishing "one-time" changes, modifications, or inspections of equipment or installation of new equipment (15:705).

Appendix B: Glossary of Variables

NAME OF FACTOR, FACTOR CHART LOCATION, UNITS:
DEFINITION

Accident Amplification Factor, R1, dimensionless:

This factor on a 0.01 to 1.0 scale describes the seriousness of the accident. The more serious the accident, the higher the factor becomes.

Accumulated Damage, R1, equivalent time periods:

Using equivalent time periods, this factor captures the amount of damage (from use and age) the aircraft has sustained by comparing actual age (in time periods) to apparent age (considering past utilization).

Adaptability Factor, D2; P2, dimensionless:

Indicates the ability of the manager to adapt to the management style and structure of the organization within which he works. This factor also includes the manager's adaptability during his/her interaction with external organizations.

Advancing Technology Combiner, R1;R2, dimensionless:

This factor measures the combining effect of technology in the case where several different systems on the aircraft can be replaced by a single system that has the same or greater functionality of the original systems.

Advancing Technology Multiplier, R1;R2, dimensionless:

This factor measures the multiplying effect of technology where the addition of advanced technology causes a ripple effect through other aircraft systems that must be modified to accept or support the new technology.

Age of Systems, R1;R2, time periods:

This is the nominal age of the aircraft systems since they were manufactured and delivered for service.

Aircraft Modifications as Percentage of BES, F2, dimensionless:

Indicates, on a scale of .01 to 1.0, what percentage of the Budget Estimate Submission is intended to fund Class III, IV and V modifications to aircraft.

Aircraft Modifications as percentage of POM, F2;F4, dimensionless:

Indicates, on a .01 to 1.0 scale, what percentage of the Air Force Program Objective Memorandum is intended for Class III, IV and V Modifications

Aircraft Modifications as percentage of President's Budget Request, F2;F3, dimensionless:

Indicates, on a .01 to 1.0 scale, what percentage of the President's Budget is Air Force aircraft modifications.

Aircraft Ownership Factor, D1;D2, dimensionless:

This factor identifies the situation in which one command has responsibility for the aircraft (or parts of it) and the other command is responsible for the modification.

Air Staff LE Approval Factor, F1, Boolean(true/false):

During the initial life of a modification requirement, the Air Staff will review all proposals and identify those that should proceed through the approval/financial sectors and those that are not yet ready to proceed. This factor, using a true/false condition, indicates the approval or disapproval of Air Staff concerning a modification requirement.

Amount of Cross-Command Interaction Required, D1; D2; P2, manhours pertime period:

This factor captures the level of involvement between Logistics Command and Systems Command required to effectively modify an aircraft. The more interaction required, the more manpower that will be required to provide the necessary level of communication and interaction.

Amount of Interaction Supplied, D2, manhours per time period:

This factor indicates the manpower provided to facilitate cross-command interaction on modification programs.

Authorizations/Appropriations Definition Factor, F2,dimensionless:

This factor describes the increasing definition, or firmness, of the actions by the Committees and the Congress on the next year's budget.

Availability of Solution, R3, dimensionless:

Used to measure the current readyness of a solution to be implemented as a modification. This factor ranges over a scale of 0.00 to 1.00. The closer this factor approaches 1.00, the greater the work done in preparing the solution (ECP, kit proof, trial install, contract award, etc).

Available Maintenance Skill Level, R1, dimensionless:

Measures the average skill level of the maintenance personnel assigned to a specific aircraft weapon system. Computed by taking the standard Air Force Skill level measures (3/5/7/9), weighted by the number of people at each level, and averaged.

Benefit/Cost Ratio, F4, dollars/dollars:

This ratio describes the benefits expected from a modification relative to the cost of the modification. It is required for any logistics deficiency modification proposal (Class IV), and so may be collected directly from documentation. Includes both cost savings and increases in or restoration of weapon system capability.

Budget Change Factor, F3, dimensionless:

The budget change factor is used to convert from the overall size of the DOD budget passed by Congress to the size of the aircraft modification budget. It combines the percent of the DOD budget approved for the aircraft modification development and production effort with the size of the approved DOD budget to arrive at the the size of the approved aircraft modification budget.

Capability Discrepancy, R2, dimensionless:

Captures the difference between enemy and United States capability by subtracting the actual capability to meet the enemy threat level from the required United States capability level.

Class IV Modification Requirement, R3, dimensionless:

This level counts the number of Class IV modification requirements that are generated by the the three different types of deficiencies (Safety, Engineering Material, and Logistics).

Class V Modification Requirement, R2;R4, dimensionless:

This level counts the number of Class V modification requirements resulting from deficiencies in capability.

Competitiveness of Mod Factor, F2;F4, dimensionless:

This factor collects those aspects of a particular mod which make it more competitive against other modifications and against other budget items. Examples of aspects include benefit/cost ratio, urgency of need, and Congressional support factor.

Complexity of Mod Implementation, P2, dimensionless:

This factor describes the level of complexity associated with the implementation of a modification on an aircraft. It considers the amount of manpower, facilities, and down time the aircraft fleet will incur during the installation of the modification as well as the technical complexity involved in the physical change itself.

Congressional Pressure to Reduce DOD Budget, F3, dimensionless:

Congress is subject to many different pressures to reduce the DOD Budget. This factor acts as an accumulator for these influences in the form of a pressure on a -1 to +1 scale. A negative value for this factor indicates that conditions are such that congress is actually in favor of increasing the DOD budget over the amount proposed by the President in his budget. A positive value for this factor indicates a pressure to reduce the DOD budget.

Congressional Support Factor, F2;F4;D1;P1, dimensionless:

This factor, which will be represented by a table function, indicates the effect of time and changing environments on the support the Congress gives for a particular mod. As the Air Force and DOD move through the POM/BES/President's Budget process for the next year-plus-one (say 1986), the Congress at the same time is moving through the First and Second Concurrent Resolutions, the Authorizations, and Appropriations Bills for the next year (thus 1985). The Authorizations/Appropriations Definition Factor captures the increasing definition, or firmness of the actions the the Committees and the Congress. This factor converts definition into a representation of support.

Corrected (modified) Support Cost, R1, dollars/time period:

This level estimates the projected support cost of an aircraft system or subsystem if a proposed Class IVC modification is implemented on the aircraft. It can be taken directly from current documentation required for logistics deficiencies.

Current Reliability, R1, time periods per failure:

This factor takes into account the other factors that impact the reliability of an aircraft system. It uses as a basis the design or inherent reliability. From this starting position, the reliability is reduced by factors like accumulated damage, age, etc. Note that the reliability of a system cannot be increased from the design reliability. Maintenance will only preserve the reliability of an aircraft system. To increase the reliability of the aircraft systems, changes to the design must be made.

Current Serviceability, R1, time to service:

This factor captures the ability of the logistics system to service and maintain an aircraft system. This factor is used in place of maintainability to emphasize the concept that one must consider the whole logistics system when measuring the serviceability of an aircraft system. This includes checks on spares, maintenance skill level, manpower constraints, facilities, etc.

Deficiency Correction Payback, R1, dollars/time period:

This factor measures the difference between the current cost to support an aircraft system and that cost to support after modification (Class IVC) of the aircraft system.

Degree of Assessed Risk, R1, dimensionless:

This factor measures the result of the mandatory risk assessment that is conducted for all safety deficiencies. The higher the assessed risk, the more importance given the safety deficiency.

Development Cycle Time, D1; D2, time periods:

Using the required number of time periods, the Development Cycle Time indicates the amount of time it takes to develop an aircraft modification from inception to preparation for transition to the production phase.

Development Management Effort Discrepancy Factor, D1; D2, dimensionless:

Using a 0.00 to 1.00 scale, this factor indicates the discrepancy or difference between the amount of development management effort required and the amount supplied. The larger the difference between the effort required and the effort supplied, the closer this factor gets to zero. Note the assumption that the organization supplying the management effort will not supply more management effort than is required.

Development Management Effort Required, Level of, D1; D2, manhours per time period:

This level accumulates the manhours required to complete the development effort for an aircraft modification program. It is measured by using the number of management manhours per time period.

Development Management Effort Supplied, Level of, D1; D2, dimensionless:

This level, like the one above, accumulates manhours supplied to complete the development effort for an aircraft modification program. It is measured by the number of management manhours per time period.

DG Modification Priority, F2, dimensionless:

This factor represents the emphasis placed on modifications in the Defense Guidance.

DOD Financial Constraint Factor, F1; F2, dollars:

This factor represents the effect of the limit, or financial constraint, within which DOD must create its POM. The postulated effect is that as the constraint gets tighter (the factor increases), the tendency to prefer modifications over new acquisition increases.

DOD-provided Air Force TOA Level, F2, dollars:

The total obligation authority level is provided to the Air Force by DoD as a bogey or target against which the Air Force then prepares its POM.

DOD Support Factor, F3, dimensionless:

Using a 0.00 to 1.00 scale, this factor measures the DOD support for a modification program. The closer this factor gets to 1.00, the higher the support found in DOD for a modification program.

Effectiveness of Development Management Effort Supplied, D1; D2, dimensionless:

This effectiveness factor uses a 0.01 to 1.00 scale to measure the effectiveness of the manhours of development management provided to a modification program. The higher this factor becomes, the better the results of the development effort.

Effectiveness of Production Management Effort Supplied, P1;P2,dimensionless:

This effectiveness factor, like the effectiveness factor forthe development sector, uses a 0.01 to 1.00 scale to measure the effectiveness of the manhours of production management provided to a modification program. The higher this factor becomes, the better the results of the production effort.

Enemy Weapon System Quantity Capability Factor, R2, dimensionless:

The effect of quantities (number of fighters, number of air-to-air missiles) on the enemy's capability, or threat to the US.

Enemy Weapon System Quality Factor, R2, dimensionless:

The effect of quality (ease of use, advanced technology application, range, reliability, etc) on the enemy's capability, or threat to the US.

Existing Modification Capacity, P1, Manhours Available per time period.

This factor measures the number of manhours available at each ALC within a given time period to preform a modification to an aircraft system.

Firmness of Design Baseline Factor, D1;P2, time periods perweighted change:

Measures the effect of changes in design on the design baseline. The firmness of the design baseline is measured using a 0.01 to 1.00 scale factor. The closer this factor approaches 1.00, the more firm the design baseline becomes. Weighing the changes recognizes the extent of the impact (drawings, procedures, parts changes, etc) of the change on the development and production sectors.

Firmness of Requirements Definition Factor D2, dimensionless:

Requirements for a specific development effort may or may not change during the development effort. This factor seeks to measure how stable the requirements are for a given development program. With a range of 0.00 to 1.00, this factor measures this stability or firmness. The larger the factor becomes, the more stable the requirements for the development program.

Fluid/Seal Failures, R1, number of failures/time period:

Counts the number of failures in the fluid systems on board an aircraft.

Funding Discrepancy Factor, D2, dimensionless:

This discrepancy, using a 0.0 to 1.0 scale, measures the difference between the funding level required and the funding level supplied for a modification program. The calculation of this factor is performed by taking the absolute value of the difference between the funding level supplied and the level required. The result of this operation is then divided by the sum of the funding level supplied and the level required. The effect is a function whose minimum is at zero (representing a firm funding profile) and whose sides asymptotically approach 1.00.

Funding Level Required, D2, dollars/time period:

Using dollars per time period, this level measures the amount of money required to complete the directed effort on a modification program.

Funding Level Supplied, D2, dollars/time period:

Using dollars per time period, this level measured the actual amount of money provided to complete the required effort on a modification program.

Funding Stability Factor, D2, time periods unmatched/totaltime periods:

This factor accumulates the funding stability history of a modification program. The number of time periods that the required funding level is not met are counted and divided by the total number of time periods elapsed. The closer this factor gets to 1.0 the greater the instability of the modification program. The closer this factor approaches zero, the more stable the funding of the modification program has been.

Government Deficit Level, F3, dollars per capita:

This variable measures the government's excess of outlays over revenues in terms of dollars of deficit per person.

Impact of Other Mods In Progress on Weapon System Factor, P2,dimensionless:

Due to the dynamic nature of the USAF aircraft fleet, several different modifications are in progress on a single aircraft system at any point in time. These modifications can and do impact each other during their development, production and implementation. This factor measures the impact of other modifications in progress on a given modification. A value of 0.00 indicates no impact while a value of 1.00 indicates a direct dependency of one modification on another.

Inherent Reliability, R1, time periods per failure:

The base or design reliability of an aircraft weapon system; measures the reliability of a weapon system before any modification or changes in usage can take place.

Inherent Serviceability, R1, dimensionless:

This is the base or design serviceability of an aircraft system. It is derived from the planned spares for the aircraft, the level of training provided to the maintenance personnel, repair and maintenance facilities provided, etc; as determined by the original design of the system.

Interaction Amplification Factor, D2, dimensionless:

Modifies the quantity of interaction by the quantity of interaction supplied and the percent of development work complete when interaction begins. It is computed by multiplying the quantity times the quality times the factor of one minus the percent development work complete.

Interaction Discrepancy Factor, D2, dimensionless:

During cross-command interaction a discrepancy may develop between the amount of interaction supplied and the amount required. Using a 0.00 to 1.00 scale, this factor measures the interaction discrepancy. The larger the value of this discrepancy factor, the larger the difference between the amount of interaction required and the interaction supplied.

Interim DOD Financial Constraint Level, R3;F1, dollars:

Measured in dollars, this level reports the dollars associated with the second year of the previous year's FYDP. This value acts as a ceiling during the competition of programs for funding.

Level of Engineering Material Deficiencies, R1, percentage:

This level accumulates support problems that degrade the mission of the aircraft.

Level of Logistics Deficiencies, R1, percentage:

This level accumulates logistic problems that result in excessive support costs for the Air Force.

Level of Safety Deficiencies, R1, percentage:

this level collects the logistics problems that are a hazard to crew members, maintenance personnel, or equipment.

Level of Validated SON's, R4, Number of SONs:

A count of the number of Statements of Need (SONs) approved as valid requirements to meet the projected threat.

Lobbyists' Pressure, F3, dimensionless:

This factor measures, on a 1.00 to 2.00 scale, the pressure applied to Congress during the budget enactment cycle by lobbyists. The closer this factor gets to 2.00, the greater the pressure applied to Congress.

Maintenance Complexity, R1, dimensionless:

A measure of the difficulty encountered by maintenance personnel in maintaining an aircraft system. It will be shown by a function of difficulty which results in hours to maintain—as difficulty increases, hours to maintain increase.

MAJCOM Support Factor, R3;R4;F1;F4, dimensionless:

Using a 0.00 to 1.00 scale, this factor measures the support given modifications by the MAJCOM. The closer this factor approaches 1.00 the greater the support given the modification program by the MAJCOM.

Manhour Backlog, R3, manhours of backlog per ALC.

During the installation of modifications, ALCs may be in a position where they have modifications that are approved and funded but cannot be installed because of manpower constraints. This constraint forces a backup of modifications and creates a backlog. Each ALC keeps track of this backlog. This variable records the level of the manhour backlog at each ALC.

Manpower Constraint Factor, D2; P2, provided/desired manpower:

This factor delineates the manpower limits placed upon an organization. Given the allocation of limited manpower to all programs, (for which an organization is responsible) the amount of required manpower in a program will exceed the amount provided. The provided manpower (in manhours per time period) is divided by the required manpower. Thus as this factor approaches 1.00, the organization is provided a greater percentage of the manpower it requires.

Manpower Pressure, R3, percentage.

Each ALC must prepare solutions to problems within a given time period using their existing staff. As more of their work force is consumed preparing solutions to deficiencies, a pressure builds to solve the old problems and turn to work on new problems. This pressure (manpower pressure) is measured on a percentage scale (0.00-1.00). It is calculated by the division of manhours used in preparation of solutions by total manhours available.

Maturity of Technology Factor, D2, dimensionless:

Using a 0.00 to 1.00 scale, this factor measures the relative maturity of a given technology. In the early stages of the development of a technology (such as the integrated circuit), the difficulty associated with moving the technology from the research laboratory to application and production cause change and new developments to take place rapidly. As knowledge and experience grow and the transfer stabilizes, these changes in the technology will slow down. With the maturity of technology factor, a measure of 1.00 indicates a new technology in the early stages of development. As the technology becomes more mature, this factor will fall off to zero.

Mission Change Factor, R1, current missions/design missions:

This factor is created by the division of the number of types of current missions flown by the aircraft by the total number of types of designed missions for the aircraft. The closer this factor approaches to 1.00 the lower the mission change factor becomes. The mission change factor acts as a multiplier for the accumulated damage factor in that as the number of design missions is exceeded by the number of current missions (i.e., use of the aircraft for new missions), the amount of damage the aircraft sustains increases. The reverse of this situation is also true.

Mod Availability Factor, R3, dimensionless.

Used to measure the current readyness of a modification to be implemented. This factor ranges over a scale of 0.00 to 1.00. The closer this factor approaches 1.00, the greater the work done in preparing the modification (ECP, development engineering complete, kit proof, trial install, contract award, etc).

Mod Development Funding Level, F3, dollars:

This variable represents the portion of the aircraft modification budget that is allocated to the development effort portion of the aircraft modification program.

Mod Production Funding Level, F3, dollars:

This variable represents the portion of the aircraft modification budget that is allocated to producing and implementing the aircraft modification.

Mod Status Review Factor, R3;F1, dimensionless:

Each proposed modification is reviewed by a team of people from the Air Staff and AFLC for its status. This factor reports the result of that review process. The more favorable the review of the modification, the larger the review factor becomes with a cap at 1.0.

Non-Modification Solutions, R1, alternatives:

This level presants the number of solutions to deficiencies that are made without processing a modification through the financial, development and production sectors. This factor includes solution of deficiencies by maintenance procedure changes, increased inspections, TCTO changes, procedural changes, etc.

Number of Configurations Serving One Need, R1, number:

This level helps to capture the logistics problems that result from different configurations of a system serving one need or function on an aircraft by measuring the number of these different configurations. The larger the number of configurations, the larger the maintenance problems supporting the different configurations. The ideal situation is only one configuration.

Number of Alternatives to Modification, F4;R1, alternatives:

This level represents the number of potential solutions to deficiencies that are made without processing a modification through the financial, development and production sectors. This factor could include solutions to deficiencies through maintenance procedure changes, increased inspections, TCTO changes, procedural changes, etc.

Number of Development New Start Approvals, D1, approvals:

This level measures the actual number of development news starts that occur during a given time period. These new starts are then added to development programs and this factor is zeroed out at the beginning of the next time period.

Number of Development Programs, D1; D2; P1, programs:

By counting the number of current development programs, this level acts as an accumulator for the addition of programs that have received approval for development, the subtraction of programs that have been cancelled or moved from development into production, and the continuation of ongoing programs.

Number of Development Program Cancellations, D1, cancellations:

This level counts the number of development programs that have been cancelled during a given time period. This factor is zeroed out at the beginning of a new time period.

Number of Implementations of Modifications Completed, P1, implementations:

Like the other accumulators, this level counts the number of implementations of modifications. The reason implementations was chosen as the quantification of modification is because measuring the number of modified aircraft would be misleading. Several different modifications are usually installed on an aircraft while it is down in the depot. By measuring the number of implementations per time period, a more accurate picture of the modification programs is presented. The level is zeroed at the end of each time period.

Number of Material Failure Accidents, R1, number of accidents:

This level measures the number of accidents sustained by an aircraft system as the result of a material failure. It does not include accidents that are the result of human error unless this error resulted directly from a material failure.

Number of Material Improvement Projects (MIPs) Opened, R1; R3, number of MIPs.

During a given time period, each ALC will open a set of MIPs to seek sloutions to deficiencies that they or the using commands have discovered and documented. This variable acts as an acculator by adding the number of new MIPs in the current time period to those MIPs still open from previous time periods.

Number of Material Improvement Projects (MIPs) Closed, R1; R3, number of MIPs.

During a given time period, each ALC will close a set of MIPs after the solution to the deficiency that created the MIP has been approved. This variable counts these MIPs as they are closed in the current time period. At the beginning of the next time period, this variable is set to zero.

Number of Production Approvals, P1, approvals:

This level measures the number of production program approvals in a given time period. Production approvals arise from the movement of modification programs from the development sector into the production sector or from the entry of modification efforts that do not require development. This level is added to the number of production programs at the end of each period and then zeroed.

Number of Production Program Cancellations, P1, cancellations:

This level accumulates the number of production programs cancelled during the current time period. Since this factor is an accumulator, it is zeroed out at the beginning of each time period.

Number of Production Programs, P1; P2, programs:

This level tallies the number of current production programs. The number of production programs is modified by the addition of new production programs and by the subtraction of completed production programs or cancelled programs.

Number of Programs Considered for Production, D1; P1, programs:

Development programs, after a given development cycle time, are considered for movement or transition from the development sector into the production sector. This variable sums the number of programs considered by management for this transfer into the production sector.

OSD/AC Mod Executability/Requirements Factor, F2, dimensionless:

This factor captures the effect of the OSD Comptroller, who reviews every proposed modification for its readiness to begin work and for the reasonableness of the requirement for the modification. The review results in either approval or disapproval, so it is represented as a switch.

OSD Issues Enactment Factor, F2, dimensionless:

This factor represents the interest OSD has in particular modifications, compared to other budget items. It is influenced by mod priorities named in the Defense Guidance, and affects the percent of the AF POM devoted to modifications.

Other (Class III) Mod Programs, F2, dollars:

Class III Mods--mods required to repair deficiencies when the weapon system responsibility has not transferred to AFLC--are considered part of the overall mod budget.

Other National Governments' Pressure for Modification, F3,dimensionless:

Other Governments exert external pressure to modify aircraft systems so the modification is available for their use in aircraft they have purchased from the United States. This factor measures this pressure on a 0 to 100 point scale. As the real pressure increases, the value of this factor approaches 100.

Percentage Applied Advanced Materials Technology, R1, percentage:

Using a 0.01 to 1.0 scale, what percentage of the aircraft was built using advanced materials technology such as composites.

Percent of Modification Capacity Utilized, P1, utilized/existing modification capacity:

This factor is created by dividing the amount of utilized modification capacity (manpower, facilities, dollars) by the total available amount of modification capacity. The closer this factor approaches to 1.00 the less modification capacity is available for additional modifications.

Percentage of Old System Affected by Modifications, R2,percentage:

Using a percentage scale, this factor measures the part of a system that will be affected by a modification. This factor measures the cascade of modifications created by a single modification because of which equipment, communication lines, power requirements, etc must change to accommodate it.

Percent of Priority List in Probable Funded Region, R4, funded PDPs/total dollars of PDPs:

Measures historical average portion of user ranked PDPs that ultimately receive funding. Certain PDPs always get funded, others usually do, and some do not ever get funded. Scale ranges from 0.01 to 0.90.

Planning for Specialized Support, R1, dimensionless:

This factor measures on a scale of 0.00 to 1.0 the amount of planning performed ahead of time for the specialized support requirements of weapon system complexity or advanced technology as it is applied to aircraft systems. The introduction of composite materials into US aircraft systems results in a different repair capability requirement than the repair of metal surfaces on older aircraft. This requirement must be planned for during the introduction of advanced technology into US aircraft systems. Also, if the system is very complex, the potential support problem is immense; sufficient planning can offset that complexity.

Payoff of Modification, F4, dollars/time period:

This factor measures the dollars spent on modification to correct a logistics deficiency against the dollars saved in projected life cycle support costs.

AD-A146 954 UNITED STATES AIR FORCE AIRCRAFT MODIFICATION PROCESS: 3/3
A SYSTEM DYNAMICS..(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF SYST..
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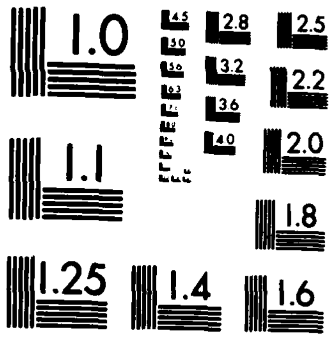


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Percent of Development Work Complete, D2, dimensionless:

Using a percentage scale, this factor measures the current amount of work completed on a development program. The higher the percentage the greater the amount of work completed on the development program.

Percent of DOD Budget Allocated to Modifications, F3,dimensionless:

This variable measures the percentage of the DOD budget that is allocated to the modification of USAF aircraft.

Perceived Threat Level, F3, dimensionless:

Using a 1 to 100 point scale, this factor captures the perceived threat level from a Congressional viewpoint. The greater the perceived threat, the closer this factor gets to 100.

Presidential Support Factor, F1, dimensionless:

The current adminstration will provide some level of support concerning DOD programs. This factor seeks to measure this support on a scale ranging between 0.00 and 1.00. The greater the value of the support factor, the greater the support received for DOD programs from the President and his adminstration.

Pressure for Acquisition, R1; R3; R4; P1, dimensionless:

This pressure is the result of the approval and funding of a modification requirement that requires the acquisition of hardware but no development. This factor measures this pressure for acquisition and applies it to the production sector on a 0.01 to 1.00 scale.

Pressure to Change Production Baseline, P2, dimensionless:

During production, pressures build to change the design baseline. This pressure is captured in this factor using a dimensionless variable on a 0.00 to 1.00 scale. The larger the value of the variable, the greater is the pressure to change the production baseline.

Pressure for Development, R1; R3 ;R4; D1, dimensionless:

This pressure, like the pressure for acquisition, is the result of the approval and funding of a modification requirement. The pressure for development is driven by modification requirements that require development work be performed before the modification is ready for production.

Priority Model factor, R3;R4, dimensionless:

This factor captures the output priority of the computer model executed by Hq AFLC. Human judgment is included in this factor since Hq AFLC reviews the output of the computer model and modifies the resulting priority list due to factors not included in the priority model.

Production Affordability Factor, P1, dimensionless:

This factor seeks to capture the decision variable that determines the affordability of a production effort. Affordability is defined by DODI 5000.1 as "the existence or ability to reprogram "funds" to support the program." It is measured by dividing funds available or reprogrammable by funds requested, on a 0.00 to 1.00 scale, the more affordable a production program is, the lower the value of the production affordability factor.

Production Efficiency, D1; P1, outputs/input:

Using the "standard" efficiency scale (0.00 to 1.00), the production efficiency of a modification program is measured. To calculate the value of this factor, a standardized output is divided by a standardized input. The primary use of this factor is to measure efficiency changes in a production program when the production schedule is compressed or expanded. During compression or expansion of the production schedule, the production efficiency will decrease.

Production Funding Stability Factor, P1, dimensionless:

Using the absolute value of the difference between the funding required and the funding supplied divided by the sum of the funding supplied and the funding required, this factor measures the stability of the funding for a production program. The result of the above calculation will result in a factor on a 0.00 to 1.00 scale where 1.00 implies low stability and 0.00 means high stability.

Production Management Effort Discrepancy Factor, P1;P2,dimensionless:

Using a 0.00 to 1.00 scale, this factor indicates the discrepancy or difference between the amount of production management effort required and the amount supplied. The larger the difference between the effort required and the effort supplied, the closer this factor gets to zero. Note the assumption that the organization supplying the management effort will not supply more management effort than is required.

Production Management Effort Required, Level of, P1;P2, manhours per time period:

This variable accumulates the amount or level of manhours of management required to complete the production effort for an aircraft modification program. This level required is measured using the number of management man hours per time period.

Production Management Effort Supplied, Level of, P1;P2, manhours per time period:

This variable, like the one above, accumulates the amount or level of manhours of management supplied to complete the production effort for an aircraft modification program. This level supplied is measured using the number of management man hours per time period.

Production Stretchout Factor, P1, actual time periods to produce base quantity/expected time periods to produce base quantity:

The production stretchout factor collects effects on a production program that tend to lengthen the time required to complete the production effort. These effects include Congressional support, production funding stability, and the firmness of the design baseline. The resulting factor measures the number of time periods actually needed or currently needed to produce a given number of modified aircraft divided by the original number of time periods expected to be needed to produce the same number of modified kits. The higher the value of the production stretchout factor, the longer the production program will be stretched out.

Program Management Experience Factor, D2, yrs experience/yrs AF:

This factor captures the experience level of a manager acting in a modification management role. The calculation of this factor counts the number of years of development and production program management experience the manager has and divides this quantity by his/her total service in the Air Force. The closer this experience factor is to 1.00, the more program management experience the manager has. Note that a balance exists between the amount of experience a manager has and the amount of training he/she has. If a manager spends all his/her time working on the job then this factor will approach 1.00 while his/her training factor will approach 0.00.

Projected cost of the Modification, R4, Dollars($):

This is the projected or estimated cost of a modification based on current dollars.

Propensity to Approve Requested DOD Budget, F3, dimensionless:

Using a 0.00 to 1.00 scale factor, this factor measures the propensity of Congress to approve the requested budget. The closer this factor approaches 1.00 the more likely Congress is to approve the requested budget. Under the current conditions of the political system, this factor will never reach or exceed 1.00.

Propensity to Develop New Systems, R2, dimensionless:

This factor is used to measure the propensity of AF management to purchase a new aircraft system rather than modify the existing system. The measurement of this propensity takes the form of a 0.00 to 1.00 scale factor where the closer the factor approaches 1.00, the greater the propensity to develop a new system.

Quality Capability Advantage Factor, R2, dimensionless:

This factor, using a scale on -1.0 to 1.0, measures the capability advantage the enemy has over the US. The larger the factor is above zero, the larger capability advantage the enemy enjoys over the US. The smaller the factor becomes below zero, the larger capability advantage the US enjoys over the enemy.

Quality of Design, R1, dimensionless:

Captures the design features that yield the initial reliability and serviceability of an aircraft weapon system. This factor includes both the planned and unplanned portions of the design and seeks to identify the combined effects of systems and subsystems on board the aircraft as they relate to the reliability and serviceability

Quality of Interaction Supplied, D2, dimensionless:

This factor measures the quality of the interaction between different commands as they participate in the accomplishment of an aircraft modification effort. It uses a 0.00 to 2.00 scale. Between zero and 1.00, the quality factor will reduce the total effectiveness of the quantity supplied; from 1.0 to 2.00, the quality factor enhances the total effectiveness of the quantity of interaction.

Quality of Managers Supplied, D2, dimensionless:

Using a 0.00 to 1.00 scale, this factor measures the quality of managers supplied to the development effort on an aircraft modification program. Programs that receive large amounts of command attention and resources (dollars and manpower) tend to receive a better quality of managers. The higher the quality of manager supplied, the closer this factor gets 1.00.

Quantity Advantage Factor, R2, dimensionless:

Using a scale of -1.0 to 1.0, this factor measures the Quantity advantage that the enemy has over the US. The higher the factor is above zero, the larger the enemy quality advantage is over the US. The smaller the factor below zero, the larger the quality advantage the US has over the enemy.

Requirements Changes, D1, changes per time period:

As time progresses, requirements for a modification development effort will change. This variable accumulates the number of changes that have occurred in a given time period. This level of changes forms a basis for a measure of the stability of a development program.

Requirements Review Group (RRG) Propensity to Approve, R4, dimensionless:

The RRG reviews all Class V modification Statements of Need (SONs) to insure that they meet a valid need. This variable measures the propensity of that group to approve a modification program as fulfilling a valid need on a range of 0.75 to 1.00.

Resistance to Baseline Changes, P2, dimensionless:

Changes to the design baseline occur during the production effort. This can result from requirements changes or from the transition of a modification program from the development sector to the production sector before completion of the development effort. This factor measures the resistance of management to these potential changes in the production baseline. This resistance is expressed on a scale from 0.01 to 1.00. The greater the actual resistance, the closer this factor gets to 1.00.

Resistance to Initial New System Investment, R2, dimensionless:

This factor represents the resistance of members of DOD, OSD, and Congress to the start of and initial investment in a new aircraft system development effort.

Safety Impact, R3;F1, dimensionless:

This factor captures the safety impact that a safety deficiency has on the system and personnel that operate and maintain the aircraft. A value of 1.00 indicates that the safety impact affects human survival. A value of 0.01 indicates little or no safety impact.

SCO/SYSTO/PEM Support Factor, F1, dimensionless:

This factor measure the level of support supplied to a modification program by the SCO (AFLC) and/or the SYSTO (AFSC) during the approval cycle of the modification program. Using a 0.01 to 1.00 scale, the closer this factor approaches to 1.00, the greater the support provided by the SCO/SYSTO.

Size of Aircraft Mod Budget Approved, F3, dollars:

This is the dollar value of the aircraft mod budget and represents the level of total dollars approved for Class III, Class V, and New Start Class IV modifications.

Size of Aircraft Mod Budget Request, F1;F2, dollars:

This is the dollar version of the aircraft mod budget and represents the level of total dollars requested for Class III, Class V, and New Start Class IV modifications.

Size of DOD Budget Approved, F3, dollars:

This level measures the actual value in dollars of the DOD budget approved by Congress for the upcoming fiscal year.

Size of President's Defense Budget, F3, dollars:

Using a dollar measure, this variable reports the total face value of the President's budget supplied to Congress for the next fiscal year.

Sortie Demand, R1, number of missions flown/time period:

Counts the number of sorties that are demanded of the aircraft in a given time period.

Sortie Mission Factor, R1, dimensionless:

Using a 0.01 to 1.0 scale, this factor identifies the type of mission the aircraft flies. The lower the factor the less demanding the mission is on the aircraft.

Spares Availability, R1, spares available when requested/total requested:

Using a percentage scale, this factor measures the percentage of spares that are available when requested versus the total spares requested.

Split of Configuration Control Factor, P2, dimensionless:

During the development and production of modifications AFLC and AFSC both have program management responsibility and/or configuration control over various systems on the aircraft. The split of configuration control factor is built by computing the

percentage of affected systems. As this factor increases, the number of systems that have split configuration control increases.

State of Economy, F3, GNP/capita:

Using the Gross National Product (in dollars) per capita, this factor provides a general state of the economy by indicating a gross income level per person for the population of the United States.

Stability of Mod Configuration Baseline, P2, dimensionless:

The stability of the modification configuration baseline is measured by counting the number of changes in one time period and dividing by the changes in the previous time period. If the result is greater than 1.00 the baseline is getting less stable; if equal to 1.00, there is no stability change; and if the result is less than 1.00 the baseline is getting more stable. If it equals zero, the baseline is absolutely stable.

Stability of Personnel, D2; P2, time periods in job:

The stability of personnel is measured by the number of time periods the worker has been assigned to his current job task. The longer he/she has been on the job, the less dynamic that job position is or the more stable that job is.

Structural/Electrical/Mechanical Wear and Tear, R1, Time:

Captures the wear and tear in terms of time (age) of an aircraft as the structural, electrical, and mechanical systems on board the aircraft are flown (much like the physiological age in humans vs nominal age).

System Complexity Factor, D1;D2, dimensionless:

This variable measures the complexity of the system being developed and produced for a modification program . The system complexity factor uses a 1 to 100 point scale. This scale is a floating measure where 100 represents the most complex system and 1 represents the least complex system. Other systems being designed and developed are placed on a linear scale from the least complex to the most complex.

TDY Funds Required, Level of, D2, dollars:

The TDY funds required variable represents the level of dollars required to accomplish the needed communication between different groups or commands involved in the development of a modification.

TDY Funds Supplied, Level of, D2, dollars:

This variable represents the actual level of TDY funds supplied to a modification program in support of the travel requirements necessary to provide communication and coordination during the development phase of the modification program.

Technology Advancement, R2, dimensionless:

This level reflects the changes in available technology since the technology incorporated in current aircraft systems and subsystems was applied. It is measured in levels or generations. Thus, vacuum tube technology is level 1, transistors are level 2, integrated circuits are level 3, large scale integrated circuits (LSIC) level 4, etc. The level in the aircraft divided by the current technology level provides a measure of the distance between the two. This level will range between 1.00 and 0.01.

Technology Factor, R1;R2, dimensionless:

This factor combines the effect of the technology multiplier and combiner to yield the net impact of advancing technology on the aircraft weapon system.

Time Criticality of Mod Factor, D2;P2, time periods to allowed IOC/FOC:

The time criticality of a modification is represented by the count of the number of time periods between the time now and the time the modified aircraft is scheduled for initial or full operation capability. Note that modification are driven by both the IOC and FOC dates. Thus this factor would be a vector with two components representing the influence of the IOC and FOC dates.

Training Factor (Development), D2, time periods training/timeperiods of AF service:

Managers spend time on training efforts. This factor measures the amount of training for program management a manager has received during his/her service with the AF by creating a ratio of time spent in training

divided by his/her total time in the AF. Note that a balance exists between the amount of training a managers has and the amount of experience he/she has. If a manager spends all his/her time on training then this factor will approach 1.00 while his/her experience factor will approach 0.00.

Training Factor (Production), P2, dimensionless:

Using a 0.00 to 1.00 scale, this factor measures the training level of personnel. The closer this factor gets to 1.00 the greater the training level of the personnel involved in the modification and maintenance of aircraft systems.

Uncorrected (current) Support Cost, R1, dollars/time period:

This factor measures the dollar amount spent each time period supporting a specific system or subsystem on an aircraft in dollars expended per time period. Most likely, this factor must be subjected to a smoothing function to remove peaks and troughs in the actual support cost.

United States Required Capability Level, R2, dimensionless:

This level measures the quantities and quality of aircraft and subsystems required to meet the threat posed by enemy capability.

United States Weapon System Quantity Capability Factor, R2,dimensionless:

This factor captures the total quantity capability of the United States aircraft weapon systems. This factor will be adapted from intelligence estimates of the US quantity capability in the same way that the quantity capability of the enemy is measured.

United States Weapon System Quality Capability Factor, R2, dimensionless:

The quality capability factor of US weapon systems represents an effectiveness of the weapon system in a threat environment. The actual quantification of this factor will require further research, but elements of availability, accuracy, range, and similar aspects should be included.

United States Weapon System Capability, Level of, P1; R1; R2, dimensionless:

With the combination of the quality and quantity capability factors, a representation of the level of US weapon system capability can be determined. This level measures the total weapon system capability of the US actually on hand and operational.

Urgency of Need/Weapon System Priority, F4;D2;P2, dimensionless:

The urgency of need/weapon system priority factor represents the overall level of priority assigned to a modification. This factor is a combination of the urgency of need for the modification and the current priority of the weapon system within which the modification is to be installed.

User Prioritized PDPs, R4, dimensionless:

Each using command ranks PDPs using a combination of weighing factors and human judgment. This level is the total dollar value of all PDPs ranked by a user.

Utilized Modification Capacity, P1, Manhours used.

This level measures the number of manhours used by a given ALC in the development and installation of modifications on aircraft.

Value of Approved Class IV Mod Proposals Submitted as PDPs, R3, dollars.

This is the level or actual dollar ammount of all the approved Class IV modification PDPs.

Value of Class IV PDPs to be Considered, R3; F1, dollars.

This variable represents the dollar value of the Class IV modification PDPs submitted to Air Staff for consideration for funding.

Value of Class V PDPs to be Considered, R4; F1, dollars.

Like the variable above, this variable represents a dollar value associated with approved PDPs. It measures the value of the Class V modification PDPs that are sent foward for funding.

Value of Modification PDPs to be Considered, F1, dollars.

This variable is the dollar sum of the modification PDPs (Class IV and Class V) that are to be considered for funding.

Value of PDPs Retained for PPBS Consideration, F1, dollars.

This level represents the dollar value of the modification PDPs that have survived the requirements review process and were included above the cutoff line for funding (based on the AF TOA). These PDPs are then ready to continue through the PPBS for competition with other programs.

Weapon System Capability Deficiency, R2, dimensionless:

Combines the difference between enemy and United States capability, as found in the capability discrepancy factor, and the current technology factor to identify deficiencies in weapon system capabilities.

Weapon System Complexity, R1, dimensionless:

This variable, measures the complexity of a weapon system on a 1 to 100 point scale. This scale is a floating measure where 100 represents the most complex weapon system and 1 represents the least complex weapon system. Other weapon systems are placed on a linear scale from the least complex to the most complex.

Appendix C: AFR 57-4 Extract

Class IV Mods Key Steps (Attachment 8)

OPCOM	1. Analyzes the assigned mission to determine the aircraft's ability to perform the tasks and functions needed to achieve the mission objective. Submits Class IVA and IVB mod requirements using AF Forms 1067 to the applicable ALC for review and integration in the budget cycle.
AFLC and ALCs	2. Analyze to find projected deficiencies, obsolescence, technological opportunities, or opportunities to reduce overall costs.
ALCs	3. Prepare and establish MIP according to AFLCR 66-15.
ALCs	4. Accomplish any preliminary engineering required to scope the problem and determine the estimated costs for submission into the budget cycle.
ALCs	5. Prepare AFLC Forms 775 according to direction in AFR 27-8. Concepts of full funding and production kit leadtime away must be complied with, as follows:
	a. Assure that the proposed installation schedules are as outlined in the applicable PDM schedule.
	b. Assure that support equipment, spares, software, and installation funds are programmed. Portrayal of these funds on the AFLC Form 775 is for visiblity purposes only and does not assure funds availability.
	c. Assure that weapons system trainers are programmed with the modification to the weapon system. Coordinate all proposals with the simulator SM and appropriate OPCOM.
ALCs and OPCOMs	d. Conduct annual priority reviews by individual weapon system.
ALCs	e. Send AFLC Forms 775 to AFLC for review and integrated prioritizing.

AFLC/LO	6. Review AFLC forms 775 for accuracy and completeness. Prepare integrated Class IV priority list. Send AFLC Forms 775 and priority list to HQ USAF/LEX/LEY.
Deputy for Avionics (aircraft only)	7. Review avionics mods to control or reduce proliferation and assure latest technology is used in avionics acquisitions.
HQ USAF/LEYY " " /LEXM " " /LEYW	8. Reviews AFLC Forms 775 for accuracy and completeness: a. HQ USAF/LEYY, LEYW prepare final priority list and publish the document. b. HQ USAF/LEYY, LEXM, LEYW in conjunction with XO and RD perpare the FY(XX) budget input. Class IV mods compete with Class III and V mods for the total P-1100/P-2100 funding. The mod budget then competes for funding within the total Air Force budget.
HQ USAF	9. HQ USAF/LEXM, LEYY, LEYW prepare the POM requirements based on the previous years unfunded mods, known new requirements which have surfaced during the previous year, and the AFSC/AFLC POM submissions.
HQ USAF	10. The POM is worked through the program review committee, and the Air Staff board structure to determine the proposed funding level in the FY program. After submission to the Office of the Secretary of Defense (OSD), several other repetitions follow before determining final budget levels for the comming FY.
HQ USAF	11 and 12. HQ USAF/LEXM prepares the Class IV portion that is based on the published priority list. Another review is conducted in OSD during the Budget Estimate Submission (BES) cycle to obtain the FY Presidents's budget submission.

ALCs	13. Prepare AFLC Form 48 according to AFLCR 57-21 in order to completely definitize the mod proposal. NOTE: AFLC Forms 48 are normally prepared after mods are programmed, but can be prepared along with AFLC Forms 775 or in advance of the budget cycle depending upon the urgency of the requirement. a. ALC CCB reviews all proposed mods. The ALC CCB provides final approval for those mods under \$2M and sends other approved mods to AFLC CCB for further processing. b. Request funds from AFLC/LOA for approved Class IV mods.
OPCOMs	14. Coordinate on the proposed mod. ASISC must coordinate on all safety mods. Assure that weapon systems are available to meet the proposed installation schedule and meet mission requirements.
AFLC	15. Reviews and approves or disapproves mods over \$2M and under \$10M. a. Sends AFLC Form 48 to USAF/LEY for final approval on mods costing more than \$10M. b. Requests mod acquisition funds from HQ USAF/LEX for programmed mods with total cost of less than \$10M. c. Sends approved, but unprogrammed, mods with total of less than \$10M to HQ USAF/LEY for possible sources of funds when the mod priority dictates immediate action.
HQ USAF	16. HQ USAF/LEYY, LEYW, LEXM keep priority list of approved, but unfunded mod requirements. HQ USAF/LEXM funds unprogrammed mod requirements if fallout funds are available based on the HQ USAF/LEYY, LEYW priority list.

HQ USAF	17. HQ USAF/LEY provides PMD approval and guidance on all class IV mods over $10M.
HQ USAF	18. Prepares implementing PMD for Air Force directed mods.
HQ USAF	19. HQ USAF/LEXM issues procurement authority (PA) for mod acquisition funds. The procurement authority specificies the quantity of kits to be procured in the applicable FY. a. HQ USAF/ACB issues the budget authority (BA). b. The PA and BA are the only documents which authorize funds expenditures for this purpose. The PA authorizes the procurement. The BA transmits actual obligation authority from HQ USAF.
AFLC	20. Manages funds for Class IV mods. Provides funds to the SM or IM after mod approval.
ALC	21. Prepares necessary documentation for acquisition efforts. Acquires necessary kits and material to accomplish mod. Ensures that support equipment, spares, trainers, etc., are acquired in time for the first kit delivery.
ALC	22. Manages installation program. Performs kit proofing.
ALC	23. Reports mod status through GO-79 system.

```
+------------------------------------------------------------------------+
|                                                                        |
|        CLASS IV MODIFICATION FLOW DIAGRAM (Attachment 9)               |
|                                                                        |
|                                            Mod    +---+ Production    |
|                                            PPBS   | A | Cycle         |
|        +----------------------+          +---------------------+       |
|        | Operating Command  1 |          |       HQ USAF       |       |
|        |   Discover and       |          |---------------------|       |
|        |   Report Deficiency  |     /---+ *Review Fm 775        |       |
|        |----------------------|    <To E| *Review & Publish     |       |
|        | AFLC               2 |     \---+  Priority List        |       |
|        |   Discover and       |          |                     |       |
|        |   Report Deficiency  |          |                   8 |       |
|        +----------+-----------+          +----------+----------+       |
|                   |                                 |                  |
|                   V                                 V                  |
|        +----------------------+          +---------------------+       |
|        |      AFLC/ALCs       |          | HQ USAF/LEXM/LEYY   |       |
|        |----------------------|          |Prepare POM Inputs   |       |
|        |  Prepare Material    |          |---------------------|       |
|        |                      +--+       |BP-1100 Program      |       |
|        |  Improvement         |  |       |Review Group (PRG)   |       |
|        |                      |  |       |---------------------|       |
|        |  Proposal (MIP)     3|  |       | Modification Review |       |
|        +----------+-----------+  |       |  Group (MRG)      9 |       |
|                   |              |       +----------+----------+       |
|                   V              |                  V                  |
|        +----------------------+  |       +---------------------+       |
|        |         ALCs         |  |       |  Program Review     |       |
|        |----------------------|  |       |   Committee (PRC)   |       |
|        |  Perform             |  |       |                     |       |
|        |                      |  |       |       and           |       |
|        |  Preliminary         |  |       |                     |       |
|        |                      |  |       |  Air Staff Board    |       |
|        |  Engineering        4|  |       |      (ASB)       10 |       |
|        +----------+-----------+  |       +----------+----------+       |
|                   |   +----------+                  |                  |
|                   V   V                             V                  |
|        +----------------------+          +---------------------+       |
|        |          ALC         |          |                     |       |
|        |----------------------|          |   Program           |       |
|        |                      |          |   Objective         |       |
|        |  Prepares AFLC       |--+       |   Memorandum        |       |
|        |                      |  |       |       (POM)         |       |
|        |  Forms 775           |  |       |                     |       |
|        |                     5|  |       |                     |       |
|        +----------+-----------+  |       +----------+----------+       |
|                   |              |                  |                  |
|                   V              |                  V                  |
|        +----------------------+  |       +---------------------+       |
|        |         AFLC         |  |       |                     |       |
|        |----------------------|  |       | BP-1100 PRG         |       |
|    /---+                      |  |       |                     |       |
|   <To A|  Review Fm 775       |  |       |---------------------|       |
|    \---+                      |  |       |                     |       |
|        |  Prepare Integrated  |  |       | MRG                 |       |
|        |  Priority List      6|  |       |                  11 |       |
|        +----------+-----------+  |       +----------+----------+       |
|                   |  +-----------+                  |                  |
|                   V  V                              V                  |
|        +----------------------+          +---------------------+       |
|        | Deputy for Avionics  |          |  PRC and ASB        |       |
|        | Control   (DAC)      |          |   Structure         |       |
|        |                      +---\      |                  12 +---\   |
|        |  Review Avionics     |To B>     |---------------------|To B>  |
|        |  Mod Proposals       +---/      |                     +---/   |
|        |                      |          |      Budget         |       |
|        |                    7 |          |                     |       |
|        +----------------------+          +---------------------+       |
|                                                                        |
+------------------------------------------------------------------------+
```

CLASS IV MODIFICATION FLOW DIAGRAM CONTINUED

B

ALCs

*Prepare Fm 48
*ALC Configuration Control Board(CCB) approval of mods under $2M 13

Operating Command

*Coordinate on FM 48
*Develop installation schedules with ALC 14

AFLC CCB

*Approve mod on Fm48
*Foward Mods greater than $10M to AF/LEY
*Request funds for Mods less than $10M 15

To D>

HQ USAF/LEY

*Approve mods > $10M
*Prioritize approved but unfunded requirements 16

HQ USAF

*Provide Program Management Directive (PDM) approval for mods over $10M 17

To C>

To D>

C

AFLC

*Prepare implementing Program Action Directive (PAD) 18

HQ USAF

*LEX issues Program Authority (PA)
*ACB issues Budget Authority (BA) 19

D

HQ AFLC

*Manage PA/BA
*Program Funding Authority
*Provide funds to ALC 20

ALC

*Manage funds for Group A&B
*Prepare Statement of Work and RFP
*Procure Mod Materials 21

ALC

*Perform Kit Proof
*Manage installation program 22

*60-79 is review Process for AFLC/ Air Staff check on Mod Program 23

Class V Mods Key Steps (Attachment 10)

OPCOM	1. Submits statement of operational need (SON) as outlined in AFR 57-1, updated by HQ USAF/RDQ letter 20 August 1981.
Other Commands and HQ USAF	2. Review and comment on SON as outlined AFR 57-1. NOTE: AFLC or AFSC provides solution alternatives with BCI and proposed PDP.
ALC/Product Division	3. For Class V mods to CIs for which AFLC has PMR, the ALC SMs prepare BCI and submit to AFLC. NOTE: For Class V mods to CIs for which AFSC still has PMR, the product division SPO project officer prepares BCI and submits to AFSC and the SON originator.
HQ USAF, RD Action Officer	4. After user submits revised SON with program and PDP, obtains final AFSC/AFLC and Air Staff coordination, and, prepares AFHQ Form 79, Requirements Summary.
HQ USAF, RD Action Officer	5. Presents SON and proposes Class V mod program, using AF HQ Form 79, to the RRG.
HQ USAF, RRG	a. Recommends that the SON and program for solution be validated or returned to originator. If validated, recommends submission to the PRG for prioritization for funds competition.
HQ USAF, AF/RDQ	b. Publishes PMD validating SON or returns SON to originator.
	c. If a Justification for Major System New Start (JMSNS) per DODD 5000.1 is needed, process remains the same. Further programming action for the FY "New Start" cannot continue until a JMSNS has been submitted with the Air Force POM and approved by Secretary of Defense in the Program Decision Memorandum (PDM). See DODD 5000.1.
HQ USAF, RRG	6. The Requirements Preview or Assessment Group, through the director level RRG, validates the need and approves the Class V mod solution, a new development program, or off-the-shelf acquisition. Validation allows the program to compete for funds. Where and

	how the solution competes for funds within the Planning, Programming, Budgeting System (PPBS) depends on the type of program validated. If no additional study, research, or advanced development is needed, the program will enter the competition for engineering development (6.4 Program Element (PE)) and/or production funds (B and C). If a 6.1, 6.2, 6.3 (technical base PEs) effort is required, the SON must compete for these funds (Go to A).
HQ USAF, RRG	7. If the validated need solution approach does not require a technical base effort but does need engineering development (6.4 PE) the program must enter competition for engineering development funds and acquisition funds simultaneously (B and C). We do not normally do engineering development until acquisition funds are included in the Air Force Program (FYDP). If no engineering development is needed, the mod can compete directly for acquisition funds(C).
HQ USAF, RD Action Officer (LE if no RDT&E is needed)	8. The validated program competes for development funds. If only a small effort is required, and it can be done with available funds, the decision can be made by the RD Director responsible for the existing program. If a large effort is required, the program must compete in the PPBS for inclusion in the POM through the appropriate panel. Block 8 could consist of no more than a discussion with a 6.3 PEM or could consist of the full PPBS. At the end, either funds are available or they are not. If no funds are available, the program can continue to compete for two full budget cycles. If only procurement funds are needed, HQ USAF/LE has OPR for the funds search.
HQ USAF, RD Action Officer (LE if no RDT&E is required)	9. If the program is still unfunded after two budget cycles, it is again reviewed for return because its priority has not been high enough to merit initiating it within current funding constraints.
HQ USAF, RD PEM	10. If funds are available, the PMD

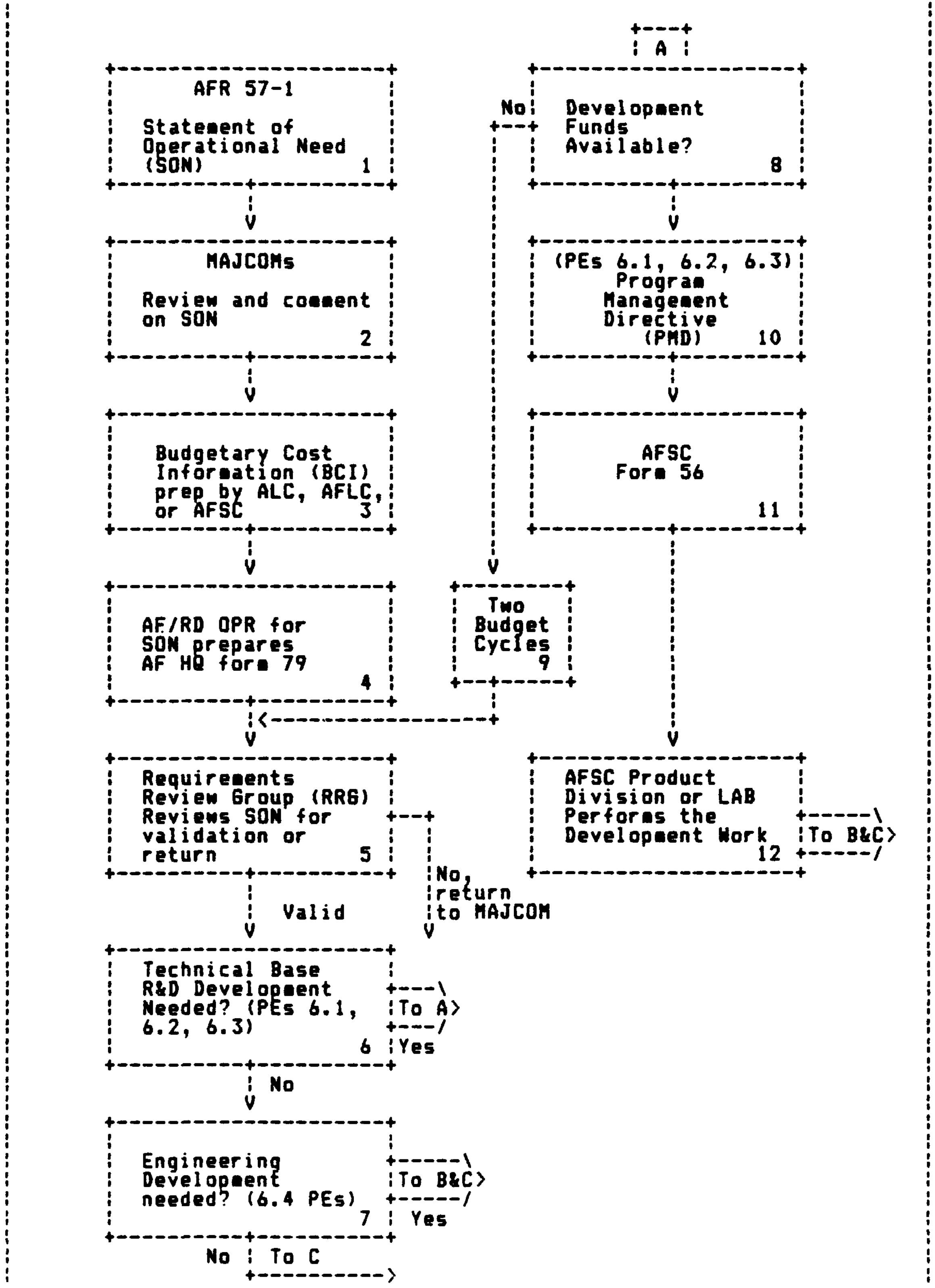
(LE if no RDT&E is needed)	directing the RDT&E or production program is issued by RD or LE respectively.
HQ AFSC (SYSTO) or AFLC/LOA	11. HQ USAF issues an AFSC Form 56 directing the program. If no RDT&E is needed, AFLC issues a Program Action Directive (PAD).
AFSC, System Division or Laboratory	12. The appropriate organization within AFSC conducts the development effort and responds with the directed product, usually including a BCI and program management plan for the subsequent portions of the program. If further 6.1, 6.2, or 6.3 effort is needed, the program enters again at A. If it is now ready for engineering development, it moves to B and C simultaneously.
HQ USAF, PEM	13. The PEMs present their proposed programs PDPs to the Air Staff Board Panels. The panels prepare proposed mission area programs for the current POM.
HQ USAF, RD Action Officer, PEM	14. Class V mods are presented both to the panels and to the PRG by the Air Force PEM with help from RD and LE action officers. The PRG prepares priority lists of the mods which are approved by HQ USAF/XOO.
HQ USAF, PRG Chairperson	15. The priority lists are provided to the PRG which prepares the proposed mod program portion of the current POM effort.
HQ USAF, LEXM, Panel Chair-people, PRG Chairperson	16. The proposed mission area (Panel) programs and the PRG are presented to the PRC which integrates them into the POM and briefs the POM through the Air Force board structure for approval (normally three exercises).
HQ USAF	17. The POM is submitted to OSD and approved by the PDM after issues are resolved.
HQ USAF, RD, LE, Action Officers and PEMs	18. The BES is now prepared based on the PDM. The PRG reviews all new start Class V mods included in the PDM. The MRG reviews each mod in the final budget. The process translates the POM

	into current year President's budget and next FYDP.
HQ USAF, OSD, OMB, Congress	19. The budget goes through the approval and appropriation process. If R&D is required, the funds will not be included in the budget unless mod funds are included in the program for a subsequent year (FYDP).
	20 If funds are available for R&D, go to D. If not, the program can compete again. If unfunded after two cycles, it goes to G for return. If included in the APDM and achieves initial funding, the mod must compete in each subsequent PPBS cycle until it is completely funded.
	21. If mod funds are appropriated are available within the current program, go to E.
HQ USAF, RD, LE Action Officers or PEMs	22. The RD PEM, RD action officer, or LE action officer, as appropriate, prepares the PMD directing engineering development, coordinates it with approiate Air Staff offices and has it signed out by the RD director.
HQ AFSC (SYSTO) or HA AFLC/LOA	23. AFSC issues an AFSC Form 56 directing the RD program. HQ AFLC assigns a mod number to the program and issues a PAD directing SM participation in engineering development.
AFSC Product Division or ALC SM	24. Prepare appropriate program management plan and submit to the approving authority. The product division normally manages development funds and the development effort. Groups A and B, data, trainer mods, and support equipment are developed and tested. IOT&E is normally conducted by AFTEC or by the using command with AFTEC monitoring. Before completion of the development program, the MPA is normally requested, so that the MRG review can take place immediately following IOT&E.
HQ USAF, RD Action Officer	25. When approaching the time for production initiation, the RD action officer will prepare the PMD requesting MPA. The PMD is coordinated and signed out by the appropriate RD director. MPAs

	are only requested if funds will be available for production.
HQ AFLC HQ AFSC (SYSTO)	26. HQ AFSC issues an AFSC Form 56 abd AFLC issues a PAD directing MPA preparation.
ALC, SM Product Division	27. The MPA is normally prepared by the ALC SM using inputs from the product division responsible for development. The ALC CCB reviews, comments and sends the MPA to AFLC.
Using Commands	28. Review and coordinate on the MPA.
AFLC, CCB HQ AFSC (SYSTO)	29. The AFLC CCB reviews, comments, and sents the MPA to HQ USAF.
HQ USAF, MRG	30. The MRG reviews the development effort, MPA, IOT&E results, and PMP to determine if the mod is ready for production. NOTE: Minimum supportability criteria must have been tested and accepted by AFLC and support equipment, simulator, or training systems development complete before scheduling the MRG for approval of production funding release.
HQ USAF RD & LEY Action Officers	31. The PMD directing implementation of the mod is prepared and coordinated by the RD PEM or action officer and signed by RD (Director) and LEY if development funds are required. If no development funds are required, the LEY action officer coordinates the PMD and LEY signs it.
HQ USAF LEX/ACB	32. HQ USAF/LEXM issues procurement authority (PA) for mod acquisition funds. The procurement authority specifies the quantity of kits to be acquired in the applicable FY. a. HQ USAF/ACB issues the budget authority (BA). b. PA and BA are the only documents which authorize funds expenditures for this purpose. Pa authorizes the procurement (go ahead); the BA transmits actual obligation authority.

HQ AFSC (SYSTO) HA AFLC	33. HQ AFSC issues an AFSC Form 56 and HQ AFLC issues a PAD directing mod implementation.
ALC/SM	34. Prepares necessary documentation for acquisition efforts. Acquires necessary kits and material to accomplish mod. Ensures that support equipment, spares, trainers, etc., are acquired in time for first kit delivery. NOTE: Normally, the SM manages the mod and sends a funded Purchase Request (PR) to the AFSC office responsible for the development which, in turn, acquires Group B, spares, and support equipment. The SM normally acquires the trial installation, if required.
Product Division	35. May acquire Group B when funds are transferred from the ALC by PR. The goal is to have fully qualified Group B equipment which would enable the ALC to aquire the total mod.
ALC	36. Manages the installation program. Performms kit proofing.
ALC	37. Reports mod status through the GO-79 system.

CLASS V MODIFICATION FLOW DIAGRAM (Attachment 11)



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  CLASS IV MODIFICATION FLOW DIAGRAM CONTINUED
         +---+                             +---+
         : B :                             : C :
+---------------------+           +--------------------+
:                     :           :                    :
:   Air Staff         :           :   AF/XO Priority   :
:   Board  Board(CCB) :<----------+   Review Group     :
:   Panel Structure   :           :      (PRG)         :
:   (HOI 21-18)     13:           :                 14 :
+---------------------+           +----------+---------+
           :                        Class V  :  Modification
           :                       Priority  :     List
           :                                 V
           :                      +--------------------+
           :                      :                    :
           :                      :    BP-1100         :
           :                      :  Program Review    :
           :                      :      Group         :
           :                      :                 15 :
           :                      +----------+---------+
           :                                 :
           :                                 V
           :                      +--------------------+
           :                      :  Program Review    :
           : Panel (Mission Area) :  Committee (PRC)   :
           +--------------------->:  AF Board          :
             Proposed Programs    :  Structure         :
                                  :                 16 :
                                  +----------+---------+
                                             :
                                             V
                                  +--------------------+
                                  :                    :
               R&D Funding        :   Program          :
           +----------------------+   Objective        :
           :(3600 Appropriation)  :   Memorandum (POM) :
           :                      :                 17 :
           :                      +----------+---------+
           :                                 :
           :                                 V
           :                      +--------------------+
           :                      :   MOD FUNDS        :
           :                      :--------------------:
           :                      :   PRG              :
           :                      :--------------------:
           :                      :   MRG           18 :
           :                      +----------+---------+
           +-------------------------------->:
                                             V
                                  +--------------------+
                                  :         AF         :
                                  :  Budget Estimate   :
           +----------------------+     Submission     :
           :                      :       (BES)        :
           :                      :                 19 :
           :                      +----------+---------+
           :                                 :
           V                                 V
+---------------------+           +--------------------+
:                     :           :                    :
:    R&D Funds        +---\       :    Modification    +---\
:    Available?       :To D>      :  Funds Availiable? :To E>
:                     +---/       :                    +---/
:                  20 :           :                 21 :
+---------------------+           +--------------------+
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+-----------------------------------------------------------------------+
|                CLASS V MODIFICATION FLOW DIAGRAM CONTINUED            |
|                    +---+                           +---+              |
|                    | D |                           | E |              |
|        +----------------------+        +----------------------+       |
|        |        PE 6.4        |        |         PDM          |       |
|        | Program Management   |        |      Requesting      |       |
|        |      Directive       |        |         MPA          |       |
|        |        (PMD)      22 |        |                   25 |       |
|        +-----+---------+------+        +-----+---------+------+       |
|              |         |                    |         |              |
|              V         V                    V         V              |
|        +----------------------+        +----------------------+       |
|        |  AFSC     | AFLC     |        |  AFSC     | AFLC     |       |
|        |  Form 56  | PAD      |        |  Form 56  | PAD      |       |
|        |           |       23 |        |           |       26 |       |
|        +-----+---------+------+        +-----+---------+------+       |
|              |         |                    |         |              |
|              V         V                    V         V              |
|        +----------------------+        +----------------------+       |
|        | Product   |   ALC    |        | Product   | ALC      |       |
|        | Division  |   (SM)   |        | Division  | (SM)     |       |
|        |           |          |        |           |          |       |
|        |----------------------|        |----------------------|       |
|        |  Prepare PMP         |        |                      |       |
|        |  Engr Development    |        |  Prepare MPA         |       |
|        |                   24 |        |                   27 |       |
|        +---+--+-------+--+----+        +----------+-----------+       |
|           |To|       |To|                         |                   |
|           \F /       \E /                         V                   |
|            \/         \/               +----------------------+       |
|                                        |        Using         |       |
|                                        |       MAJCOM         |       |
|                                        |    Coordination      |       |
|                                        |                   28 |       |
|                                        +----------+-----------+       |
|                                                   |                   |
|                                                   V                   |
|                                        +----------------------+       |
|                                        |         AFSC         |       |
|                                        |----------------------|       |
|                                        |    Concur & Foward   |       |
|                                        |----------------------|       |
|                                        |       AFLC CCB       |       |
|                                        +---------+--+---------+       |
|                                                  |To|                 |
|                                                  \F /                 |
|                                                   \/                  |
+-----------------------------------------------------------------------+
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+---------------------------------------------------------------------------+
|              CLASS V MODIFICATION FLOW DIAGRAM CONTINUED                  |
|                                                                           |
|                 +---+                                                     |
|                 | F |                                                     |
|        +--------+---+------+                                              |
|        |       MRG         |                                              |
|        |    Review for     |                                              |
|        |    Production     |                                              |
|        |    Readiness      |                                              |
|        |               30  |                                              |
|        +---------+---------+                                              |
|                  |                                                        |
|                  V                                                        |
|        +-------------------+                                              |
|        |                   |                                              |
|        |       PDM         |                                              |
|        |    Directing      |                                              |
|        |       MOD         |                                              |
|        |               31  |                                              |
|        +---------+---------+                                              |
|                  |                                                        |
|                  V                                                        |
|        +-------------------+                                              |
|        |     PA & BA       |                                              |
|        | AF/LEX Issues     |                                              |
|        | Program Authority |                                              |
|        | AF/ACB Issues     |                                              |
|        | Budget Authority 32|                                             |
|        +---------+---------+                                              |
|                  |                                                        |
|                  V                                                        |
|        +-------------------+                                              |
|        |         |         |                                              |
|        | AFSC    | AFLC    |                                              |
|        | Form 56 | PAD     |                                              |
|        |         |         |                                              |
|        |         |     33  |                                              |
|        +---------+---------+                                              |
|                  |                                                        |
|                  V                                                        |
|        +-------------------+                                              |
|        |     ALC/SM        |                                              |
|        | Manages Funds     |                                              |
|        | Procures Group A kit|                                            |
|        | PR's Group B funds|                                              |
|        | to AFSC       34  |                                              |
|        +---------+---------+                                              |
|                  |                                                        |
|                  V                                                        |
|        +-------------------+                                              |
|        |  Product Division |                                              |
|        | Procures Group B Kit|                                            |
|        | Procures peculier |                                              |
|        | S.E. and spares when|                                            |
|        | AFLC PR's Funds 35|                                              |
|        +---------+---------+                                              |
|                  |                                                        |
|                  V                                                        |
|        +-------------------+          +---------------------+             |
|        |   AFLC SM does    |          | Reporting Status    |             |
|        |   Kit proofing,   |          | via 60-79 AFLC/     |             |
|        |   Manages         +--------->| Air Staff Progress  |             |
|        |   installation    |          | Monitering          |             |
|        |               36  |          |                 37  |             |
|        +-------------------+          +---------------------+             |
|                                                                           |
+---------------------------------------------------------------------------+
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Appendix D: Interview Guides

Discussion of the Interviews

The interviews of policy-makers and decision-makers within the Air Force aircraft modification process were accomplished in two phases. The first or initial set of questions for the interview sessions were of an informational and background type. The intent during these first interviews was to gain an understanding of the overall modification process and to identify the different organizations inside and outside DOD that influenced the modification process.

During the second set of interviews, the initial information gathered was presented to the interviewees in the form of a conceptual model. The interviewees were provided an introduction to the modeling technology employed for the construction of the model. Once they understood the technology, a guided discussion followed. During the presentation of the model the interviewee was asked to comment on and help correct flaws in the relationships described by the model. Correction of the flows enabled the model to better represent the actual structure of the modification process.

The guides used during the interviews are presented in the following two sections. Note that these guides were intended only to be the foundation of the interview.

Managers of the process had different levels of experience, responsibility and understanding of the process. It was necessary to explore the experience and understanding of the manager to determine the areas in which each could contribute. For this reason, no interview followed these guides exactly.

Interview Guide 1: Initial Interview

1. Introduction and Overview.

   A. Introduce Self.

   B. Describe Purpose of Research Effort.

      1. Policy Analysis.

      2. System Dynamics Technology.

      3. Identify the Bounds of the Research.
         a. Limited to Aircraft Modification.
         b. Class IV and Class V Modifications.
         c. Resource Allocation.

      4. Topics to be Covered During Interview.
         a. Role of your organization in Mods.
         b. Requirements Generation Interface.
         c. Requirements Rewiew Interface.
         d. PPBS Interface.
         e. Implementation Interface.

2. Discussion of Interviewee's Role in Mod Process.

3. Discussion of Requirements Generation and Review.
   A. Class IV Requirements.
   B. Class V Requirements.
   C. Who Advocates Mod Programs?
   D. Explain Requirements Validation Step (IV&V).

4. Discussion of PPBS Cycle Involvement.
   A. Explain POM Process at Your Level.
   B. Describe Congressional Activity During PPBS.
   C. Explain Full Funding Concept.
   D. Comment on 3600 R&D vs 3010 Sustaining Engr.

5. Discussion of Mod Implementation.

   A. Split Management Issues.
   B. Difference Between Small and Large Mods.
   C. Confuguration Management Issues.

6. Discussion of Problems that Exist in Process.

   A. Structural Problems.
   B. Organizational Problems.
   C. Personality Problems.

7. Summary and Outbrief.
   A. Class IV Reference List (Written, People).
   B. Class V Reference List (Written, People).

Interview Guide 2: Model Validation Interviews.

1. Introduction and Overview.

   A. Cover What has Been Done Since Last Trip.

   B. Review Purpose of Research Effort.

   C. Topics to be Covered During Interview.
      1. Conceptual Model of Mod Process.
      2. Areas of Concern in Model Structure.
      3. Potential Flaws in model.

   D. Introduce Causal Loop Technology.
      1. Example from Requirements Sector.
      2. Have Interviewee Describe Relationships to Insure Complete Understanding of the Technology.
      3. Emphasize that Causal Diagrams are not Flow Diagrams.

2. Discussion of Conceptual Model (Using Diagrams).

   A. Requirements/Capability Sector.

   B. Financial Sector.

   C. Development Sector.

   D. Production Sector.

3. Discussion of Problems that Exist in Models.

   A. Structural Problems.
   B. Relational Problems.

4. Summary and Outbrief.

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A conceptual model of the Air Force aircraft modification process was developed and validated. The model was designed using the system dynamics technology and is a tool to extend the knowledge and understanding of the decision and policy-makers within the modification process. Sources of information used in the development of the model included both literature research and personal interviews. The personal interviews were conducted with Air Force, DOD, OMB, and Congressional people active in the aircraft modification process. Five key issues concerning the behavior of the system were identified and detailed. These issues were: the lack of a systems approach to modification management, the absence of a Class IV requirements approval process, the difficulties of management split between AFSC and AFLC, the priority ranking of modifications by the financial community, and the weaknesses of the process which are currently overcome by strong individuals. Five recommendations for change to the modification process were presented. The recommendations were to establish a requirements review, approval, and ranking process for Class IV modifications, encourage a systems approach to management, improve the credibility and understanding of the process, and encourage competition by several means. Use of the conceptual model provides the manager with a deeper understanding of the complex modification process and can provide greater visibility into the potential outcomes of policy changes.

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